Doctoral Thesis

MOVEMENTS IN PERCEPTION ON HUMAN FECES FOR TRANSITION SANITATION DESIGN, USING CONVERGENCE OF SCIENCE AND ARTS

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Department of Urban and Environmental Engineering
(Convergence of Science and Arts)

Graduate School of UNIST

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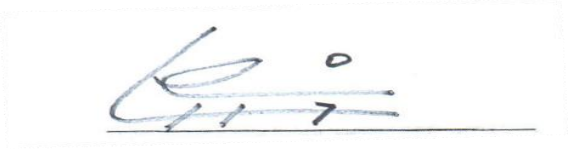

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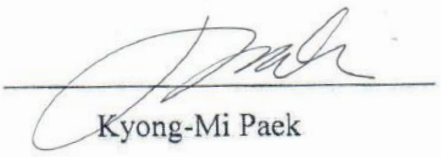

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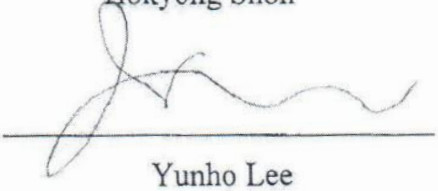

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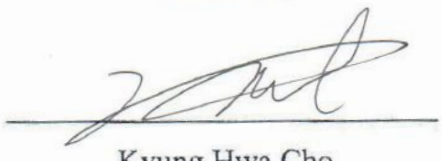

Kyung Hwa Cho

ABSTRACT

The invention of the flush toilet system has facilitated the rapid removal of human feces from dwellings and other buildings, thereby vastly improving sanitation conditions. However, a “flush-and-forget” approach is enabled by this system, which exacerbates environmental problems, as it increases indifference to the treatment of human waste. The result is that the environment receives a massive contaminant flow from the countless flushing toilet systems. In an effort to solve the problem, scientists and engineers have tried to improve the technological treatment efficiency of human waste. However, considered from a different perspective, the targeted problem could be changed from the technologies for the treatment of human waste to human perceptions on feces, as, after all, feces are produced by everyone. Thus, feces can be a key issue to solve the environmental problems related to flush toilets.

To study feces as a problem, a qualitative research approach is required, as feces is related to the human perception of it and, therefore, a quantitative research method is not enough to study it. In this dissertation, in an effort to create a breakthrough, a convergence of the methodologies of the sciences and the arts was used. This method was designed to consider human factors in a scientific research method, which means that human reason from the sciences and human intuition from the arts were combined to change human perceptions on feces in an effort to solve the environmental problem.

In conducting the study, various scientific aspects were investigated, such as the analysis of the bio-molecular composition of different types of compost, the characterization of urine, and the estimation of the removal efficiency of contaminants by constructed wetlands. Subsequently, artists and their artworks on the meaning of feces were studied as the artistic aspects. These results were provided to interviewees during individual in-depth interviews for the qualitative research. The perceptions on the interviewees on feces before and after the interviews were compared to determine how their perceptions had changed.

During the interviews, interviewees’ perceptions were changed partially from the negative perceptions to positive by reducing the unsubstantiated negative images obtained from the education system or the neighborhood. The convergence of science and the arts could influence people to reconsider the meaning of feces and the reason for treating feces simply as disgusting objects, even though they are the products of humans.

According to Kant, images are materials for making perceptions. The images of feces are negative; therefore, the perceptions are negative. However, the perceptions, including touching, smelling, and seeing feces without disgust can be a powerful driving force to break away from the flushing toilet system. Similarly, the research methodology of the convergence of science and the arts can be applied to create an alternative solution for various social problems that are related to the conflicts between human perceptions and technologies such as artificial intelligence, genetically modified organics, and the desalination of water for drinking.

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CHAPTER 1

INTRODUCTION

1.1 Flush toilet and excreta

The scarcity of fresh water has become a considerable problem over the last few decades. According to the recent annual risk report from the World Economic Forum, water crises ranked third in the list of global risks in terms of their effects [1]. The changing global hydroclimate, as well as socioeconomic conditions, leads to increasing water demands [2]. As regards the socioeconomic factors, rising living standards and increasing interest in health and sanitation are the driving forces for the rising demand for domestic water. The flush toilet system has reduced the incidences of diarrheal diseases and parasitic infections, and has improved human sanitation. This sanitation system has reduced by 71% the prevalence of the *Ascaris. App* parasite among all age groups in the USA [3]. In Malaysia, flush toilets have reduced infant mortality by 82% [4]. However, despite such overwhelming advantages, the flush toilet system has become a source of water pollution. 43 % of total nitrogen in the influent of raw wastewater originated from the human feces [5]. Furthermore, large volumes of potable water are used to transport human excreta. Some studies have reported that toilet water usage was a main contributor to the household water demand. In Korea, toilet water accounted for the largest volume (38.5 lpcd) of household water consumption [6].]. Data from Australia indicate that showers use the most water (50 lpcd), with washing of clothes ranking second (30 lpcd), and toilet flushing using 21.1 lpcd [7]. As office buildings, institutes, and schools release the largest volume of wastewater from the flush toilets, the huge amount of potable water consumption also can be predicted. This means that flush toilets use fresh water and produce wastewater. In addition, the treatment (sewer) system for the collected wastewater has started to cause problems, as rapid urbanization and the growing populations in cities require larger treatment plants. It turn, this demands more operating energy, leading to cost increases. In the USA., reportedly, approximately 3% of the entire local energy demand is needed to treat and convey wastewater [8]. Moreover, wastewater treatment plants were pointed out as hotspots for the release of antibiotics. The particular study reported that the use of pharmaceuticals for various purposes increased their concentration in the influent and effluent of wastewater treatment plants [9].

As regards the psychological aspects, the flush toilet system has contributed to the aggravation of environmental pollution. The “drop-and-discharge” approach is a convenient and comfortable solution for disposing of human excreta, as it rapidly removes the hazardous and unpleasant matter from households [10]. However, the complete detachment between people and their own excreta

has contributed to environmental problems. People discharge their excreta unconsciously, forcing the environment to receive and deal with a massive contaminant waste flow.

1.2 Environmental engineering and Convergence of Science and Arts

The flush toilet and centralized wastewater treatment system are considered major achievements of the environmental engineering field; however, the negative side is that these inventions contribute to difficult environmental challenges. However, it can be a chance to reconsider the role of the environmental engineering in human society. It is also the time to change the traditional research area and methodology which were involved in the civil engineering field. Furthermore, alternative research methodology for the improving the originality of environmental engineering should be provided. Recently, environmental engineering has passed the boundaries of the civil engineering field and it is currently focusing on the treatment of pollution and not only on the design of treatment plants. Furthermore, the environmental engineering study area includes human society and the ecosystem. Such characteristics lead to the extension of the research field to include other science subjects, such as chemistry, biology, physics, and ecology [11]. However, because of the mixing of various disciplines, the originality in environmental engineering has waned. Scientists from other disciplines, such as chemists, biologists, or physicists could easily study environmental engineering, and could even provide solutions superior to those of the experts in the environmental engineering field. In order to become an independent discipline, with originality and creativity, environmental engineering has to establish its own research methodology.

To change and improve the study characteristics of environmental engineering, it is necessary to realize the limitations of science. The sociologist, Ulrich Beck, mentioned that the radicalization of modernity increases the risk in society, with the uncertainty of science being one of the critical factors [12]. The radical progress of science has improved human life by producing convenient devices such as the motor car, refrigerator, robot, and others. However, the side-effects from these conveniences were a somewhat unexpected development. The dangers are treating people in directly or indirectly. Environmental problems such as smog and climate change affect human health directly, but depression derived from the progress of technology is an indirect result. Therefore, Ulrich Beck insists that science should be developed carefully and various aspects have to be discussed, because scientific subjectivity is always based on the reported experiments [13].

Scientific inventions have contributed to human contentment and, today, most people in developed countries live in relative comfort. However, this does not imply that people are happier than before, even in the most advanced countries [14]. People are still trying to find solutions to complex human problems with scientific methods. Obviously, science has promoted the quality of human life;

however, it is dubious whether science could solve all the difficult problems in human society in the future. This is because material affluence and comfort are not the only or even the most important factors in human well-being. Emotion is a most powerful component of the human mind when people are making choices. However, the sciences exclude the role and validity of the human mind, emphasizing only absolute factors, such as numbers or matter. The philosophy of modern science is characterized by positivism, i.e., a theory based on the epistemological aspect that true knowledge can originate only from sensory experience interpreted by reason and logic [15]. As emotional judgement is excluded, people easily believe in scientific objectivity. Modern scientific methodology, governed by positivism, has been applied in various studies; however, excluding human emotional judgement has caused human alienation from the environment. As the scientific facts are considered the only important aspects, people assume it is preferable to exclude and repress emotion when conducting tasks. Because science is a tool that seeks to reveal the truth, it does not have any judgmental aspects. Scientific results can lead to various social results according to the usage and when problems arise, people simply conduct studies again with the scientific methods. However, the scientific results obtained could give rise to new problems; therefore, the question is how to get rid of this "vicious cycle"? The solution could be to establish an alternative method to solve the various complex problems. Accordingly, a new concept of environmental engineering, based on an alternative study methodology, should be provided in an effort to reduce such problems.

The convergence of science and the arts was suggested as alternative study methodology to solve problems. Several such convergence studies have been conducted, but the methodology of the current study differs from these, with the originality of the current study being the convergence between the sciences and the arts. Usually, such convergence studies are conducted as interdisciplinary research in a science field, such as chemistry and mathematics, biology and physics, or chemistry and physics. However, the current methodology attempts to fuse science with the arts. In considering two factors, namely, reason from science and intuition from the arts, the current methodology could provide an alternative solution. In addition, this methodology could aid a move away from scientism, i.e., a blind belief in the power of scientific knowledge and technology.

1.3 A suggested approach to environmental engineering

To many people, environmental engineering is a study focusing on the treatment of hazardous contaminants. However, environmental engineering has become an interdisciplinary field, including energy, politics, and economic issues, as the social problems have become more complex. To solve such complex social problems, environmental engineering has worked together with various disciplines, such as chemistry, biology, and mathematics. However, because of excessive cooperation with the other disciplines, the academic originality of environmental engineering has

decreased. Therefore, to break out of this deadlock, an alternative environmental engineering concept with a different viewpoint is suggested

1.3.1 Environment, Cognition, and Environmental engineering

A first step in suggesting such an alternative concept of environmental engineering is the characterization of the environmental engineering discipline. “Interaction” is an important concept in environmental engineering, as the discipline interacts with other disciplines and it seeks to find a solution between people and matter. Therefore, the interaction between science and human factors can be the connecting point to the methodology of the convergence of science and the arts.

The second step in this process is defining the keywords. According to the English dictionary, the term environment has two major definitions. The first is the circumstances, objects, or conditions surrounding humans. The second definition is the complex of physical, chemical, and biotic factors (as climate, soil, and living things) that act upon an organism or an ecological community, and ultimately determines its form and survival. The first definition is a more general meaning and people usually associate beautiful scenes of nature with the word “environment”. The second definition is closer to the concept of environmental engineering, focusing on the pollution aspect that of necessity has led to the discipline becoming chemistry-based knowledge. It is obvious that chemistry-based environmental engineering has succeeded in solving various serious problems and it has improved human sanitation conditions. However, various types of environmental problems have indicated the limitations of the previous approach, as it has become difficult to treat the thousands of chemical products that are being produced every day. There could be discrepancy between the view of the public and that of the environmental engineering discipline about the word “environment”. In this study, the first definition is used in order to reflect the human aspect and to suggest an alternative concept.

If the first definition is accepted, the word “surround” should be reconsidered as a keyword in the alternative concept of environmental engineering because it determines the boundaries of the environment. The expanded meaning of environmental engineering, including the concept of surroundings, can provide a useful approach to solving complex problems. The surroundings can be defined as the boundary of the personal limitations of cognitive capacity. This is the reason for people being unable to recognize matter without individual background knowledge. In addition, people cannot "feel" the surroundings without cognition. The dictionary definition of cognition is "the mental action or process of acquiring knowledge and understanding through thought, experience

and the senses". The meaning can therefore be considered as an interaction with the environment. Acquiring knowledge includes having a question from and an answer by us. The action of questioning and answering can be a process that interacts with the environment. Therefore, if the concept of surroundings is included, the boundary of the environment should be reconsidered. The meaning of environment can be considered as everything contained within the personal limitation of cognitive capacity. For example, these can be components of the environment such as matter, language, community, study, and the like. Such components interact with personal life and can therefore change the range of the limitation of cognitive capacity. According to this approach, with the word "interaction," the relation between people and their surroundings is important to the meaning of environment in an alternative concept of environmental engineering.

1.3.2 Perception, Essence and Qualitative method in Environmental engineering

In his book, *The Critique of Pure Reason* [16],], Kant states that, "...the imagination is a necessary ingredient of perception itself..." His opinion is that imagination is a component of perception. According to Kant's statement, the negative perceptions on feces could be caused by negative images. Some images are obtained from the senses, whereas others can derive from education. Feces have been considered hazardous and dirty matter. This concept is certified knowledge from human history to date. However, accumulated knowledge in human society is helping to change the feelings about matters. For example, accumulated knowledge has taught people that a virus could be used as a vaccine, and that a solar eclipse is nothing to be afraid of. There are because of changing of perceptions. The changing of perceptions also implies that the images of the phenomena have undergone change. Therefore, the changing of perceptions on feces could affect human life by providing various ideas not belong to negative perceptions when people sense matter.

The definition of the word "e*ssence*" originates from Aristotle, namely, "the what is was to be" (literal translation). In addition, he links "essence" to the meaning of "definition," "a definition is an account that signifies an essence." This can be confusing, as Aristotle did not define the meaning of "essence" by "definition". The Oxford Learner's Dictionary defines essence as, "the most important quality or feature of something, that makes it what it is". It is obvious that it is not easy to understand the word "essence"; however, many scholars try to find the essence of matters in scientific and liberal ways.

These two words, perception and essence, are important in the study of the perceptions on feces, but it is difficult to investigate with scientific methodology. This is because these words are related to the human mind; therefore, qualitative research methodology, focusing on an interview and behaviors, is required. The qualitative method aims to understand a culture or a person completely.

It differs from quantitative methodology, in which statistical results and numbers are important factors. Qualitative research, focusing on perception and essence, is necessary for the concept of alternative environmental engineering that can consider human factors.

However, it could appear difficult to apply qualitative methodology in the engineering field because numbers have the significant power in this field. Moreover, most people think that results without numbers cannot be trusted. At this point, the originality of the alternative concept of environmental engineering exists. The keyword, "interaction," refers not only to the calculated results but also to the qualitative results, which relate to the human mind. As regards the human mind, it is possible only to use the qualitative method. A lack of objectivity can be pointed out in relation to this approach, as interviews or behaviors are relative and subjective results. However, it can be questioned whether science is always objective. In his book, *The Structure of Scientific Revolutions* [17].], Thomas Samuel Kuhn mentioned that normal science is a puzzle-solving. This statement implies that normally it is not the aim of science to make creative products; it simply tries to confirm the expected results in a paradigm. According to Kuhn, science already has a subjective character because scientists tend to fix the results before their experiments and afterwards try to persuade people to accept their results; consequently, science can be considered not totally objective. This view can aid understanding of the application of qualitative research in the alternative environmental engineering. The important point is not what the subject or object is, but what the essence of the study topic is. Therefore, applying the qualitative method in environmental engineering for studying interaction could be an effective study approach.

1.3.3 Alternative environmental engineering with convergence of science and arts methodology

By re-defining the keywords, an alternative concept of environmental engineering can be proposed. In order to determine the academic originality, environmental engineering should consider carefully the relation between people and their surroundings. The alternative concept of environmental engineering considers the relation between people and surrounding and focuses on the feedback system to improve people and surrounding. This implies that environmental engineering is not only a scientific study but also a convergence study. The converged environmental engineering requires a new study methodology that combines human intuition and scientific knowledge. For instance, when a reducing contaminant process is studied, the new methodology should consider the relation and meaning of the contaminant in human society, and not restrict the study to the characteristics of the problematic materials. The methodology also provides an alternative solution to establish a symbiotic relationship between people and the contaminant, because contaminants cannot be classified as such by the arbitrary decision of a human being. This approach means the converged

environmental engineering comprises both science and humanity. As regards the scientific aspects, the characteristics of a contaminant are studied, such as toxicity, degradability, or diffusivity. As regards the humanity aspect, the reason for the material being considered a contaminant in human society can be studied. Accordingly, the methodology of the new concept of environmental engineering can be suggested from the previous discussions. The methodology follows the procedure "observation, represented appearances, focus on the interaction, experiments, and expression of the results **(Figure 1.1)**. According to this methodology, environmental engineering can be a study about the interaction between people and their surroundings. In addition, it could be a study about a point of contingency between people and their surroundings. This concept could enable an engineering discipline that is able to consider human factors.

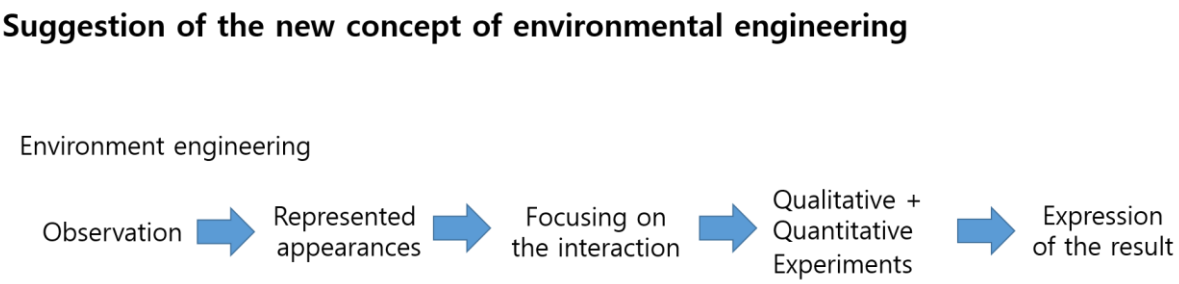

Figure 1.1 Suggestion of the alternative concept of environmental engineering

From the examples and the characteristics of the methodology of science and the arts, the methodology of the convergence of science and the arts can be suggested. The crucial aspect is to apply the contingency concept to scientific methodology. In considering the interaction between people and an object before formulating a hypothesis, it could change the tendency of science to exclude human factors.

It follows from this methodology that science can include the contingency concept and human factors. In addition, the arts can exist at the core of scientific methodology, as the characteristic of the arts is the primary step in the research. This approach could change the existing concept of science. Existing science has attempted to find absolute scientific knowledge. In the process from observation to conclusion, science allows only a small margin of knowledge, because the existing science accepted accurate and precious data without any exception. However, the new methodology will suggest comprehensive flow for the solution. The new methodology does not focus only on the matter but also considers the human factors and enables consensual scientific knowledge. In addition, the new methodology will be able to reduce the distance between people and science.

CHAPTER 2

Background and related research

2.1 Brief history of environmental engineering

The term "environmental engineering" was not used until the 1960s, as the discipline was a specific part of civil engineering. Civil engineers designed public facilities, so they designed the water supply and wastewater drainage to control environmental pollution and protect public health [18]. As the nomadic lifestyle of people changed into a sedentary lifestyle, waste was generated, and water and public health problems emerged [11]. As cities became larger, the demand for water increased, as well as the volumes of wastewater and waste. People have to find a place to dispose of their daily waste. During the Middle Ages, people simply threw out their waste into the street because there was no sewerage system (**Figure 2.1**). Therefore, water contamination and sanitation for human surroundings have emerged as important issues. Thus, water contamination and sanitation for human surrounding has emerged as an important issue. In the early 1850s, a cholera (waterborne disease) outbreak occurred in London, as the drinking water had been contaminated by raw sewage containing the cholera-causing bacteria [19]. In an area of only a few street blocks, approximately 500 deaths occurred in a period of 10 days. In December 1952, the Lethal London Fog occurred, leading to the death, from the acute effects of smog, of approximately 12,000 people during the period December 1952 to February 1953 [20]. After this episode, the United Kingdom enacted the Clean Air Act of 1956.

The discipline of environmental engineering draws on the knowledge of other disciplines, such as biology, chemistry, mathematics, and ecology to solve pollution problems. In becoming more interconnected with other science and engineering fields, environmental engineering has increasingly departed from the classic field of environmental engineering that is considered a part of civil engineering. A classic definition of environmental engineering is given by the American Society of Civil Engineering (ASCE, 1977):

"*Environmental engineering is manifest by sound engineering thought and practice in the solution of problems of environmental sanitation, notably in the provision of safe, palatable, and ample public water supplies; the proper disposal of or recycle of wastewater and solid wastes; the adequate drainage of urban and rural areas for proper sanitation; and the control of water, soil, and atmospheric pollution, and the social and environmental impact of these solutions. Furthermore, it*

is concerned with engineering problems in the field of public health, such as control of arthropod-borne diseases, the elimination of industrial health hazards, and the provision of adequate sanitation in urban, rural, and recreational areas, and the effect of technological advances on the environment"

Figure 2.1 "Gardyloo!" De damno per ejecta (1554) Yale Law Library

However, currently, environmental engineering also relates to energy, politics, and economic problems. The discipline concerns not only environmental pollution but also social influence derived from political choices. This current direction is reflected by the character of environmental problems that relate to diverse fields. The European Commission regulates the permits for industrial installations, collected in the IPPC Directive of 1966 [21]. Therefore, recently, the interconnected character of environmental engineering has been enhanced.

2.2 Science and Arts

2.2.1 Brief history of science and arts

Modern science and arts derived from the Greek liberal humanities. In Greece, philosophers were interested in human society, ethics, and nature, i.e., there was no clear division between science and the arts. In early Greek, the arts were included in the *techne*, which is a Latin word, and means activities such as handcrafts, farming, or cooking [22]. The antonym of *techne* is *episteme,* which is located in the domain of knowledge. The Greek philosophers Socrates and Plato considered the arts

only as an aesthetic aspect of philosophy, not as an important part what modern people sensed. The nine muses of Greek mythology relate slightly to the modern arts. These muses are Clio, Euterpe, Thalia, Melpomene, Terpsichore, Erato, Polymnia, Urania, and Calliope, relating, respectively, to history, music, comedy, tragedy, dance, poetry, choral, astronomy, and heroic poems [23]. The modern concept of the arts was introduced in the 18th century. Previously, no category could distinguish between the arts and human activities, such as is explained by *techne*. During the medieval period, the concept of the arts was divided into the liberal and mechanical arts. The liberal arts were categorized as music, arithmetic, geometry, astronomy, grammar, logic, and rhetoric. The subjects of mechanical arts were wool spinning, armature, navigation, agriculture, venation, medicine, and theatrics [24]. In 1746, Charles Batteux attempted to define and limit the concept of the arts, which included sculpture, painting, music, poetry, and dance [25]. Although it was no perfect theory, it was the first attempt to establish the modern art system. Science became a defined discipline with the creation of the word "scientist" by William Whewell in 1833. G.S. Wu mentioned that science had already separated from the matrix of philosophy; therefore, the word "scientist" could be created [24]. Historically, science and art were separated by Charles Batteux and William Whewell when they defined the concept and sub-disciplines of science and the arts. Furthermore, the encyclopedists of the 18th century used the two words, namely, science and art. As these words were used in a book that was regarded as containing all human knowledge, people readily accepted the concept of science and the arts as different fields.

Science and the arts are linked closely because of their origin. Sometimes, the interactions of science and the arts produced significant results. For example, Pythagoras was a philosopher, mathematician, and musician. His contribution to music is the Pythagorean scale. The story is that he heard sounds from a blacksmith's shop when walking in the vicinity. He discerned the different pitches of the sounds of the hammering from the different weights of the hammers. From this discovery, he experimented with musical tones and ratios and created the Pythagorean scale [26]. Another example is Leonardo da Vinci, whose numerous masterpieces indirectly showed his ability as scientist and artist. He tended to apply scientific knowledge to his artworks. For instance, in his painting of the *Mona Lisa*, he used the aerial perspective technique [27], i.e., indicating the relative distance of objects or the landscape by degrees of clarity, tone, and colour. This technique can be seen in the background of the *Mona Lisa* painting (**Figure 2.2**).

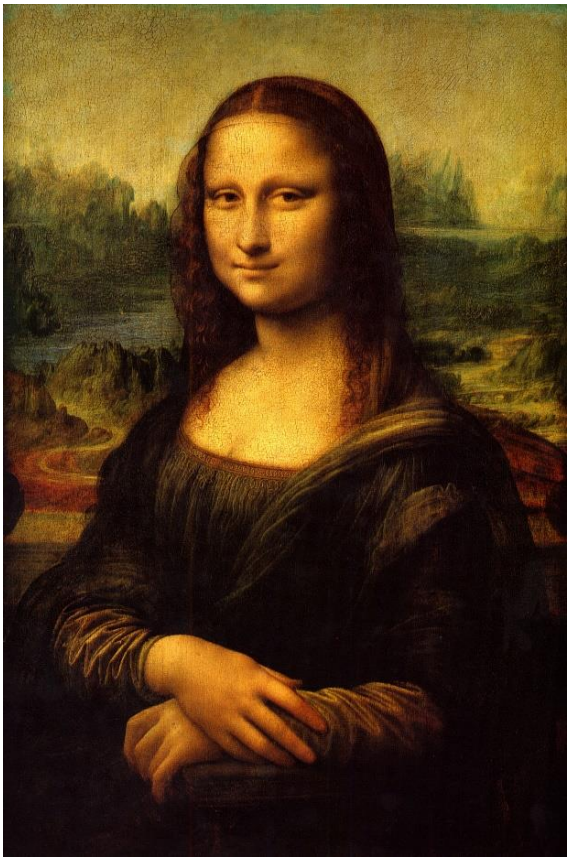

Figure 2.2 Leonardo da Vinci, *Mona Lisa* / La Gioconda (1503), oil on poplar panel, 79.4 x 53.4 cm. Muse´e du Louvre, Paris. Photo credit: Re´union des Muse´es Nationaux / Art Resource, New York.

2.2.2 Study methodology of Science and Arts

Art and science both start with the observation of objects, using the senses, and transforming it to represent appearances, using analysis followed by synthesis, or a method with unity through intuition. From the hypotheses, science attempts to create knowledge such as theories, whereas the arts attempt to create new forms of expressing art [28]. Jacob Bronowski, a mathematician, historian of science, and theatre author, said that there was a likeness between the creative acts of the mind in art and in science [29]. Furthermore, in his book *The Evolution of Physics*, Albert Einstein mentioned that science was not simply a collection of laws, or a catalogue of unrelated facts. Science is a creation of the human mind, with its freely invented ideas and concepts [30]. Therefore, creativity is common in both science and the arts..

However, science, of necessity, employs various principles, such as cause and effect; however, art does not follow this principle. Instead, the arts employ contingency, which is the main difference in the methodology of the arts and science (contingency versus necessity).

According to D. Pritchard, contingency can be defined by contingent, which is an event if it occurs in our real world, but does not occur in the general class of the nearest possible worlds in which the relevant initial conditions for that event are the same as in our world [31]. In addition, necessity is

the idea that everything happens inevitably without possibility. It is also defined as a statement that cannot be incompatible. Accordingly, contingency tends to be close to momentariness and variability, but necessity inclines to perpetuity and absoluteness. It is not easy to find the concept of necessity in some artistic works. In contrast, contingency concepts are uncommon in scientific work. The arts express results by using emotions; however, science shows the results with the intellect and without feelings. Mae Jemison, an astronaut, medical doctor, and art collector, in a TED talk, said that science provides an understanding of a universal experience, whereas the arts provide a universal understanding of a personal experience.

From these characteristics of the science and arts, a flow chart to explain the different methodologies of science and the arts is proposed (**Figure 2.3**). The first step of the research methodology of scientists and artists is observation. Subsequently, in the second step, they image the represented appearances from the matter. From these appearances, the artists can suggest that A is B. Their opinion comes from the inspiration that is experienced in that moment. This is a contingency concept. However, the scientists formulate a hypothesis, i.e., A will be B from the represented appearances, as they reason that there is inevitability between A and B. This is a necessity concept. After this step, artists practice to express their impressions. Scientists conduct experiments to find the cause and effect results. Finally, artists show new forms by abstracting characteristics, whereas scientists suggest a new theory with rules or principles.

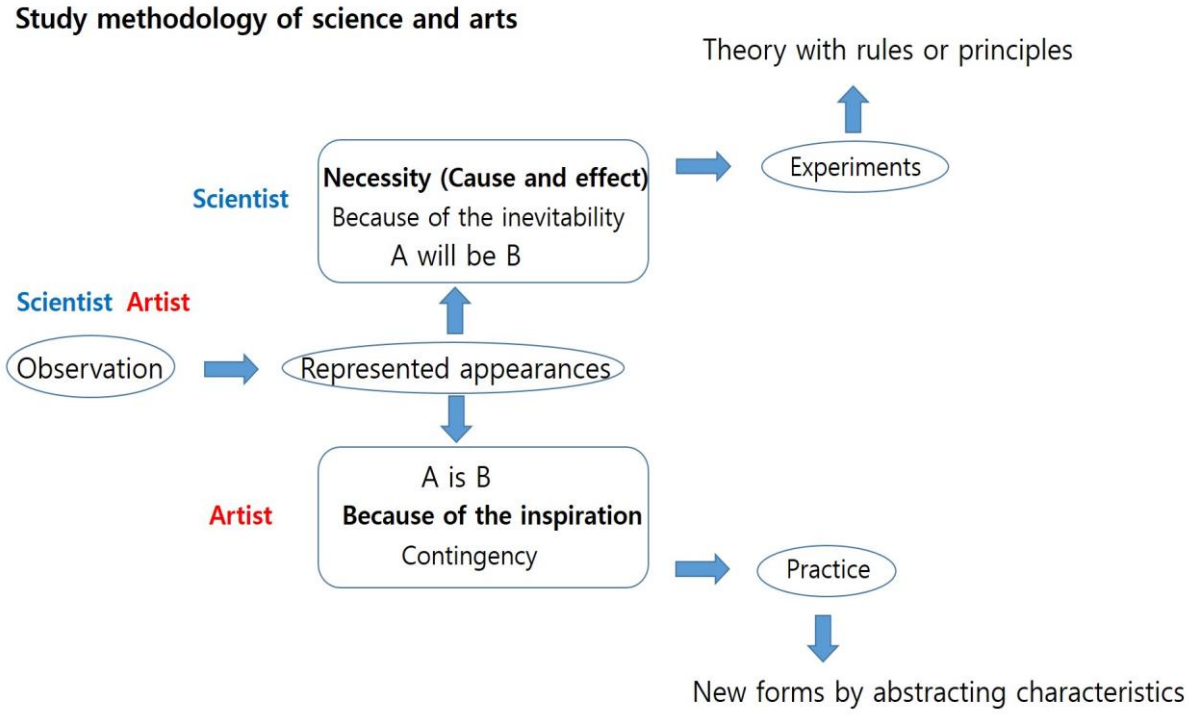

Figure 2.3 Study methodology of science and arts

Claude Monet, a leading member of the French Impressionist art movement, attempted to capture the qualities of the changing light in nature. Impressionism is a genre that emphasizes the observation of nature rather than the imagination. Monet, particularly, was interested in the depiction of light and the effects of the changing light on the landscape [32]. In his painting *Morning at Antibes* (**Figure 2.4**), Monet struggled to depict the Mediterranean sunlight. From his observation to his painting, he followed artistic methodology in this painting. The painting shows qualities of momentariness and variability because of the properties of the landscape.

Figure 2.4 Claude Monet. Antibes. Le matin (Morning at Antibes). 1888. Oil on canvas. Philadelphia Museum of Art. Philadelphia

Scientists have also studied light to explain the color of the sky. Ironically, Leonardo da Vinci has been called the "father of skylight optics." He was interested in the color of the sky because he was troubled by aerial perspective when painting landscapes. Da Vinci thought that atmospheric turbidity related to the whitening of the sky. After this opinion became known, various scientists attempted to determine the scientific reasons for describing the sky as blue. In 1871, Rayleigh reported that the light from the sky could be explained by scattering from the molecules of air. This is an instance of the necessity concept of science [33].

These examples show the difference between artists and scientists. The concepts of contingency and necessity define the different characteristics of artists and scientists; however, the other steps in studying objects are similar. Both scientists and artists need a certain level of responsiveness to receive objects from the outer world into their inner world. Moreover, they need intuition to transform the object to represent the appearance and the intuited essence. In addition, they need the ability of understanding to create concepts from the unified representation and intuited essence.

2.2.3 Convergence studies

The convergence of various fields of science has been studied already. In particular, nanotechnology, biotechnology, information, and cognition (NBIC) are receiving attention from scientific and political communities [34]. According to Phillip Sharp, a Nobel Prize winner, convergence will be a vital requirement for advancement in many crucial areas. He said that researchers needed to learn a type of "convergence creole" to help them communicate across disciplinary lines and, subsequently, to become fully "multilingual" [35] The convergence of science and art has been studied in an attempt to increase creativity in research fields. According to Hegel [36], architecture is located on the lowest level, in terms of the aspects of dealing with our spirit in connection to the outer world. Instead, science is used, especially mathematical laws, such as geometry (symmetry, intentional asymmetry) and structural mechanics (force balance). Most architecture, if architects design with artistic intention, has symbolic parts that represent something important to the architect or the building, and which have to harmonize with the architecture and the other components. Architecture often utilizes other art forms, including statues, painting, and music (the ringing of bells in the tower and the divine sounds of a pipe organ inside the building). Stained glass windows with beautiful decorations can screen the too bright light from outside and facilitate the use of candles in a cathedral. Scientists could make use of this concept of the harmony of the composites, at least in practicing their scientific intuition when conducting scientific research. Recently, the convergence of science and the arts has been applied to education for improving the imaginative and artistic emotional capabilities of students, as well as understanding the science content. As reported by Ahn, the understanding of scientific knowledge could be improved by using artistic optical illusions [37]. This author introduced anamorphic art to elementary students. This type of art describes an object from a distorted perspective; therefore, requiring a specific vantage point. Ahn's method was to first show anamorphic artworks to the students and to explain the principle. Subsequently, artworks were created together with the students. This educational approach improved the concentration and activeness of the students. A respondent to the survey in the study said that the method was interesting because, "I can directly apply what I have learned in class."

2.3 Composition of feces

The fecal organic matter has been studied in fields such as sanitation and composting. A poor feces disposal system affects human health and contaminates the water and soil. However, the composting process could change feces into good soil amendments or fertilizers. The literature indicates [38, 39], that the median fecal wet mass production is 128 g/cap/day, with a median dry mass of 29 g/cap/day. The nutrient elements in feces are reportedly 0.35–0.87 g/cap/day of total P and 0.9–4.9 g/cap/day of total N. Sato et al. [40] referred to the malodor-causing volatile substances, a major factor in the

negative perception of feces. As reported, 90 % of malodor-producing substances were the fatty acids, namely, acetic acid, propionic acid, and butyric acid. Indole, skatole, pyridine, pyrrole, hydrogen sulfide, and methyl mercaptan were indicated as minor malodor-producing substances. Bacteria in the human body play an important role in human health as an active complex community. Bacteria facilitate the digestion of food, metabolism of endogenous and exogenous compounds, immunopotentiation, and they prevent colonization by pathogens in the human intestines [41]. The predominant genera reported are *Bacteroides*, *Eubacterium*, *Clostridium*, *Ruminococcus*, *Peptococcus*, *Peptostreptococcus*, *Bifidobacterium*, and *Fusobacterium*. Bifidobacterium and *Bacteroides*, in particular, are well known as bacteria beneficial to human beings. However, other bacteria can cause pathogenic illness; therefore, proper hygiene after coming into contact with excreta is crucially important.

Table 2.1 Daily per capita of organic and inorganic compounds in feces (by C. Rose et al. [39])

(g/cap/day)

Organic compounds		Inorganic compounds	
Protein	3.2 -16.2	Total P	0.35 - 2.7
Carbohydrate	4 – 24	Total K	0.2 - 2.25
Fat	1.9 - 6.4	Total N	0.9 - 4.9
Dietary fiber	0.5 – 24.8		

2.4 Natural organic matter study in Environmental engineering

As feces comprise organic matters, the natural organic matter analysis method is utilized in environmental engineering. Natural organic matter (NOM) is ubiquitous in water, sediment, and soil, and is defined as a complex mixture of organic materials in water. It originates from plants, animals, including human beings, and their debris. The hydraulic cycle facilitates the occurrence of NOM in water, even in drinking-water sources. Therefore, it is important to control the occurrence of NOM in drinking-water treatment plants, as it affects color and taste, and could contain harmful substances such as disinfection byproducts (DBPs) [42]. However, the various origins and different decomposition pathways make the characterization of NOM difficult. NOM can be characterized by various parameters, such as molecular weight and size, chemical charge, hydrophobicity, chemical functional groups, and structure [43]. NOM is named after such particular characteristics; for example, the biodegradability of NOM is termed biodegradable organic matter (BOM), and the

NOM residue on filters is called particulate organic matter (POM) [44]. This NOM analysis method can be applied to different types of samples in the environment.

2.4.1 NOM fractionation and Preparative HPLC

Natural organic matter (NOM) is regarded as a problematic material (e.g., a membrane foulant) in water treatment systems [45] and as a disinfection byproduct (DBP) precursor [46]. However, it is also a crucial component in aquatic ecosystems as an energy source for the microorganisms. Although the NOM plays an important role in the aquatic environment, information about NOM characteristics is inadequate. Much of the resulting uncertainty is due to the heterogeneity and complexity of NOM. To obtain detailed and specific characteristics of NOM, fractionation is widely used (e.g., XAD resin, ultrafiltration, size exclusion chromatography). Preparative high-performance liquid chromatography (prep-HPLC) has been employed as a purification procedure in chemical, food, and pharmaceutical research field. Recently, this system with a large volume SEC column has been applied to characterize NOM, using various detectors [47-49]. These studies were conducted under different prep-HPLC operating conditions because the system operating condition depends on the column properties. With the prep-HPLC system, various types of columns are available, but eluent type, flow rate, and the sample injection volume should follow the instructions provided by the column manufacturer. The instructions guarantee the analytical efficiency of the column, but this can be a limiting factor to design an experiment that is satisfactory for research purpose. Thus, some researchers have made preparative columns in their laboratories to conduct specific experiments suitable for their purposes [50-52].

Although many papers have been published about prep-HPLC using handmade columns, there are only a few studies evaluating column-packing efficiency. In most studies, separation efficiency of the manually packed columns was estimated graphically, by comparing the chromatograms made by the packed column and a ready-made column. However, quantitative evaluation of the packed column performance is important because the calculated values help in diagnosis of the column-packing state and the operating condition of the system. Column performance is represented by several parameters, which include the number of plates (N), asymmetry factor (As), the height equivalent to a theoretical plate (HETP), and column resolution (Rs). These parameters show specific conditions of the packed column, but are influenced by the system operating conditions. These include the composition of eluents, flow rate, column length, and particle size [53]. Thus, it is necessary to evaluate a manually packed column using the numbers calculated in relation to the operating conditions.

2.4.2 NOM molecular structure with Pyrolysis GC/MS system

NOM is a complex mixture because of its origin. The exact structure of NOM has not been determined, but its proposed structure is reported as being aromatic and aliphatic hydrocarbon structures connected with various functional groups (**Figure 2.5**) [54]. Various analytical methods have been used to investigate the molecular structure, such as specific UV absorbance (SUVA), nuclear magnetic resonance (NMR), and pyrolysis gas chromatography/mass spectrometry (GC/MS).

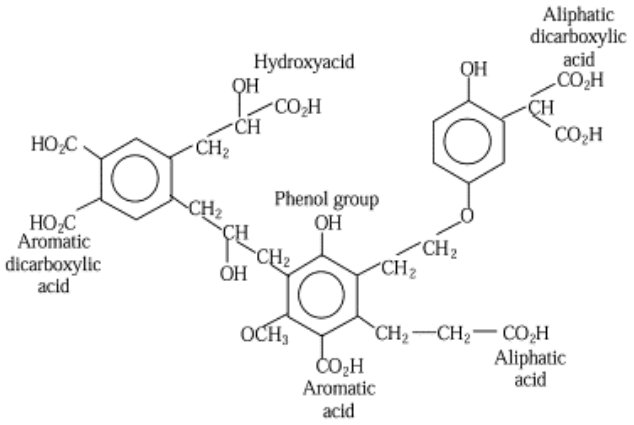

Figure 2.5 Proposed molecular structure of humic acid, adapted from Duan and Gregory [54]

SUVA is defined as the UV absorbance at 254 nm of the sample divided by the dissolved organic carbon (DOC) concentration. A higher SUVA value means that a high concentration of hydrophobic NOM exists in the sample, as the aromatic structure absorbs more UV light than the aliphatic structure does [55]. Therefore, the SUVA value can provide an indirect index of NOM in terms of aromatic or double-bonding structures. NMR has been used to understand the chemical bonding of NOM and is a more direct approach concerning the structure than SUVA is. The NMR phenomenon occurs when the nuclei are affected by the external electromagnetic field. To arrange the nuclei, different energy from the external electromagnetic field is used, depending on the type of nuclei, and the detector determines the energy absorbed by the nuclei. Following this process, NMR provides the chemical structure of NOM. Many studies have been conducted on humic acid and fulvic acid [56, 57].

The pyrolysis GC/MS analytical method utilizes thermal decomposition. Following rapid heating to a high temperature without oxygen, biopolymers such as NOM are decomposed into low-molecular-weight compounds. Because this method provides the specific fragments originating from bulk NOM, it can interpret clearly the building blocks of NOM. Greenwood et al. reported on the

molecular characterization of the DOM of wastewater effluents by utilizing pyrolysis GC/MS, introducing 21 molecular structures decomposed from the DOM in the effluents (**Figure 2.6**) [58].

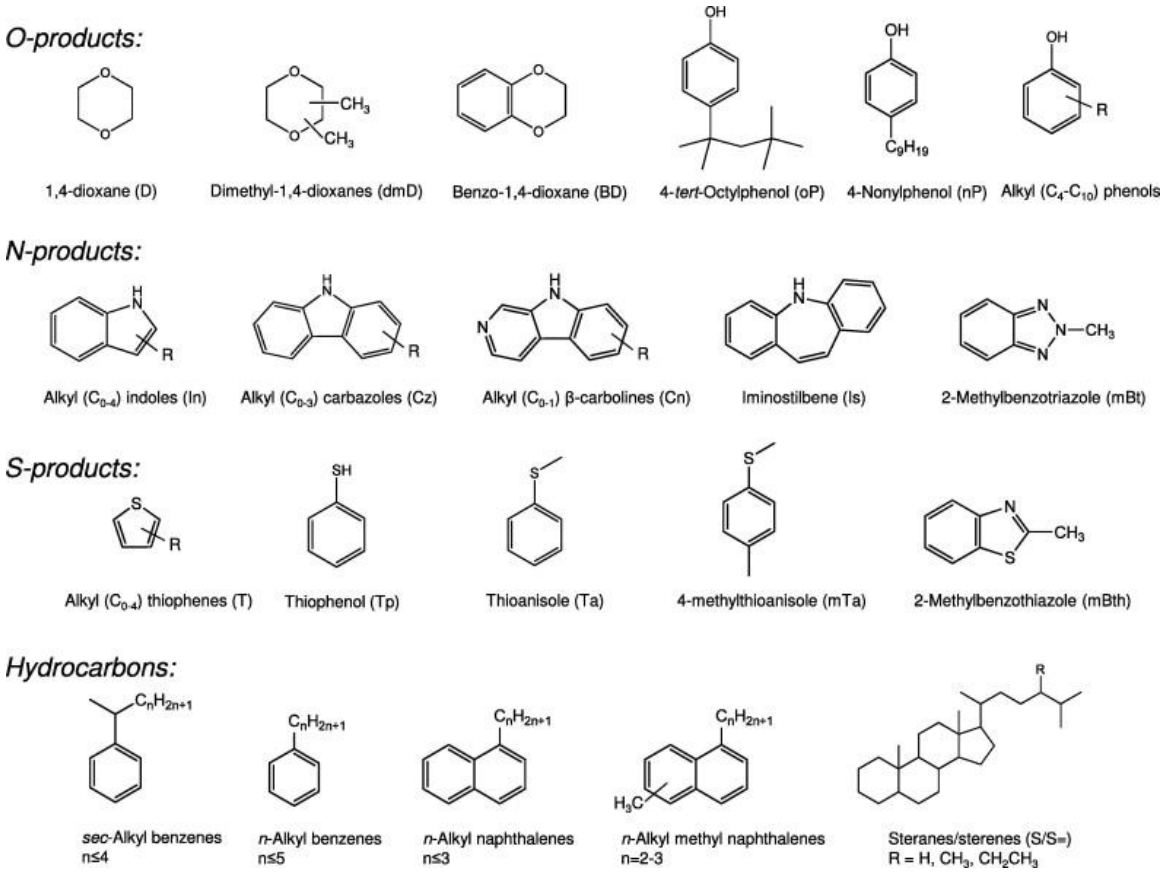

Figure 2.6 Molecular structures of several pyrolysis products. Adapted from Greenwood *et al* [58].

CHAPTER 3

OBJECTIVES, HYPOTHESES AND RESEARCH STRUCTURE

3.1 Research problem statement

In modern society, negative perceptions on feces have increased to use flush toilets. These sanitation systems consume massive volumes of clean water and contaminate water resources. To reduce such waste of water resources and prevent water contamination, effective wastewater treatment systems and flush toilets have been developed. However, the negative perceptions, i.e., that feces are dirty and dangerous persist in human society. These technologies cannot solve the human waste problem because they exclude the meaning of feces. Therefore, it is necessary to change the negative perception that feces should be removed from our society as soon as possible into the positive perception that feces are valuable to our society.

3.2 Objectives and scope

The primary objective of this study is to investigate human perceptions on feces, which could contribute to solving the problems associated with the flush toilet system. To achieve the research goal, specific objectives are suggested, namely:

1. Defining the new research methodology

2. Applying the methodology to an environmental engineering study

3. Providing a solution for the flush toilet problem with an investigation of human perceptions on feces.

The first objective focuses on the establishment of a new research methodology, i.e., the convergence of the science and arts methodologies. The second objective explains the applicability of the method to existing environmental engineering practice. The third objective shows the solution suggested by the convergence of the science and the arts methods.

The research scope of this study includes the humanities and the science fields. Art is a representative humanities study that relates to human emotion. This liberal arts discipline was investigated in order to incorporate the associated artistic expressiveness and intuition into the scientific method. The existing meaning of feces in our society was investigated by applying qualitative research methodology to the study of human perceptions.

3.3 Hypotheses

The convergence of science and arts methodology can provide an opportunity to reconsider the existing meaning and the compositions of feces by the individual in-depth interviews including artistic and scientific information. The results could be utilized to change the negative perceptions on feces, as fundamental information can be obtained to solve the problems caused by the flush toilet system.

3.4 Research structure

Chapter 1 (Introduction) and Chapter 2 (Background and related research) describe the history and role of science and arts in human society. This information was used to explain the necessity of the convergence of science and arts. In these chapters, the difference between the existing and suggested convergence of science and arts concept is introduced. Subsequently, these data inform the rest of the dissertation.

Chapter 3 (Objectives, hypotheses, and research structure) explains in detail the research objectives. The objectives are clarified, and the hypotheses are described in relation to the research problem. To promote understanding of the flow of the dissertation, the research structure is described with a schematic flow chart.

Chapter 4 (Methodology) explains the various study methods for convergence of science and arts. The major study method relates to the qualitative research method, as the convergence point would be the human mind, which cannot be measured with quantitative data. The analytical method for suggesting scientific data and the biographical research method for providing artistic data are introduced. Subsequently, the results are used in the individual in-depth interviews to verify the convergence results related to the human mind.

In Chapter 5 (Analyses of feces and urine, and constructed wetland for water treatment), the scientific results of feces are presented. The chemical compositions, ion species, volatile organic compounds, and microbial community of feces are investigated. In comparing the ion concentrations between compost and commercial soil, the value of feces as an effective fertilizer is considered. In addition, the ion concentrations of urine, according to the storage date, are measured to verify its usefulness as a liquid fertilizer. The aim of presenting the results of the study on the chemical information of feces and urine is to suggest quantitative data to the interviewees, without any emotional judgement. Subsequently, constructed wetland operating data are reported to show an alternative wastewater treatment system without blackwater (wastewater containing feces and urine).

Chapter 6 (Biographical research of the artists who created their artworks with excreta) describes the artistic aspects of feces. These results were used for suggesting artistic and epistemic information to the interviewees. By investigating the artworks of two artists (*Artist's Shit* by Manzoni, and *Doggy Poo* by Kwon Chong-saeng), the meaning of feces in human society is considered.

In Chapter 7 (Individual in-depth interview for applying the methodology of the convergence of science and arts), an attempt is made to change the negative perceptions on feces in the human mind. This is done by introducing the study results of Chapters 6 and 7 during the individual in-depth interviews. Scientific and artistic information about feces is suggested. Subsequently, changeable and unchangeable perceptions on feces are studied by comparing the mind maps that were drawn before and after the interviews.

Chapter 8 (Summary and conclusion) is the final part of the current dissertation, in which the application of the convergence of the methodology of science and arts for changing negative human perceptions on feces is summarized.

Chapter 9 (Contribution of convergence works to the society) reports on two projects aimed at realizing the study results of the convergence of science and arts fields. The feces standard money (FSM) and the waterless drying toilet are introduced and their roles in the future are discussed.

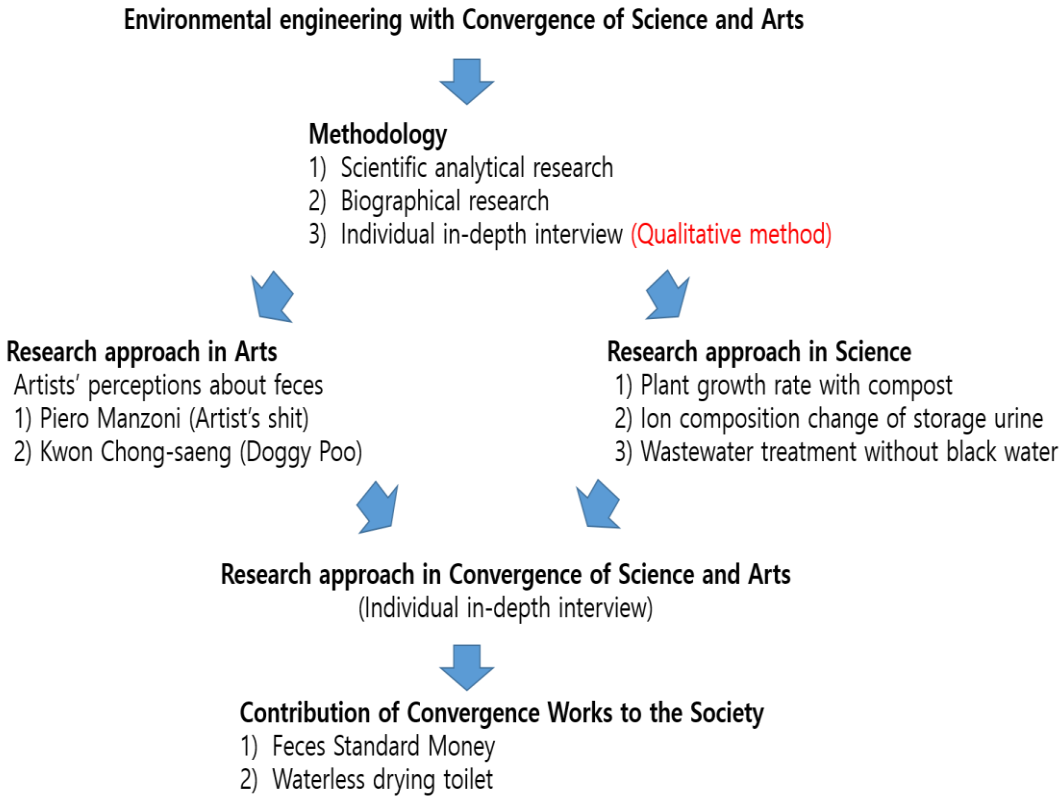

Figure 3.1 Schematic flow chart about research structure

CHAPTER 4

Methodology

4.1 Overview of the methodology

This methodology is based on a mixed research method, which combines the qualitative and quantitative methods. The quantitative method is used for the verification of a hypothesis, with statistical and numerical results. On the other hand, the qualitative method is used for the interpretation or the understanding of a research topic. However, each method has limitations. The quantitative method has the advantage of generality, but its weak point is the inability to interpret specific situations, such as perceptions or ideologies. The qualitative method is useful to understand conceptual topics, but it is open to criticism because of the possibility of bias from arbitrary interpretations. Therefore, the complementary strategy of the mixed research method is employed to reduce these limitations [59].

This dissertation aims to study the change in human perceptions on feces by employing the convergence of science and arts methodology. Science is included in the quantitative research and the arts are represented in the qualitative research aspect. The final goal of this study on converging science and arts match the purpose of the mixed method. Scientific quantitative and artistic qualitative results about feces are provided to change human perceptions. This strategy is included in a concurrent method among the different types of a mixed method. In this method, researchers collect the two types of results and combine them to interpret the research topics. In applying the mixed method to this study, detailed and valuable findings could be obtained.

The methodology has three steps, namely, 1) scientific analytical research of feces with experiments, 2) biographical research of the artists who created their artworks with excreta, 3) individual in-depth interviews for the convergence of science and arts in the human mind

The findings from the first step and the second step will be provided to interviewees as supplementary data, which, in the last step, can induce a change in individual perceptions on feces. This process can define the aspects of the perceptions on feces that can be changed and those that cannot be changed. Therefore, this study suggests that the results of the convergence of science and arts will be appeared in human mind, according to the contingency and necessity requirements of the arts and science (**Figure 4.1**).

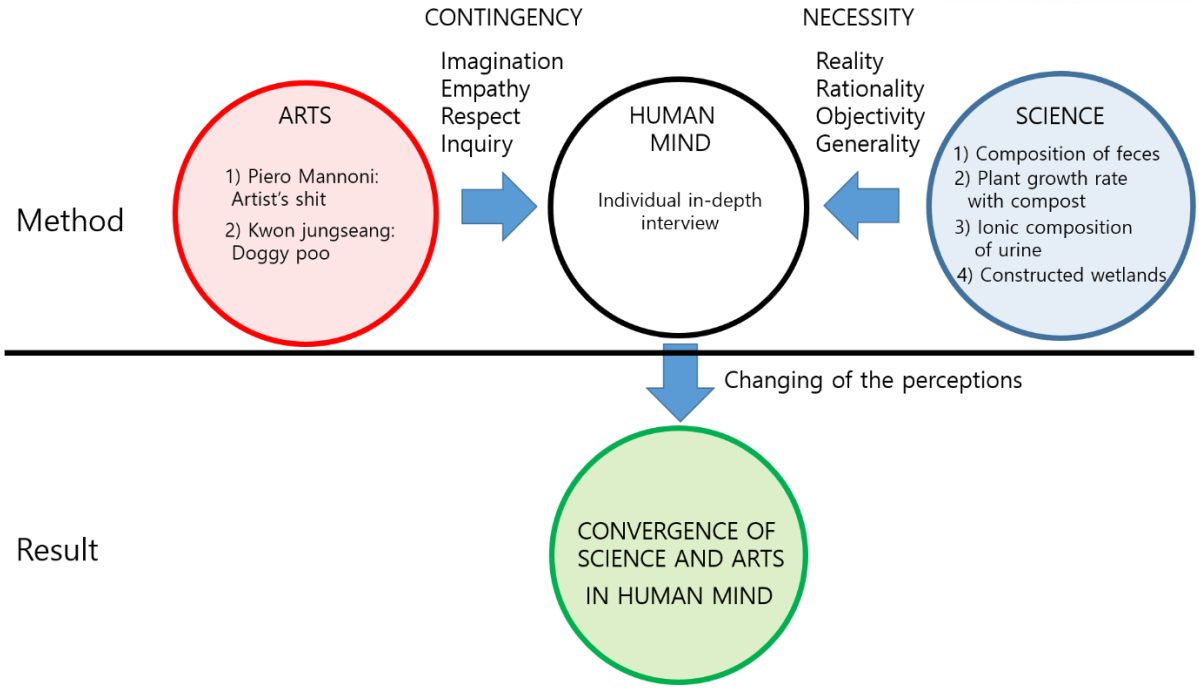

Figure 4.1 Schematic diagram for methodology

4.2 limitations of the methodology

First, the perceptions and special opinions of the selected artists could be inadequate, as only two artists were studied. Artists are sensitive people and their artworks are varied and special. In the current study, the opinions of the artists could be uncommon and the opinions could vary according to the selected artists. However, the biographical method aims to determine the different opinions and special experiences of the lives of the artists. Therefore, it is important to investigate the perceptive opinions of the artists about feces, even though the results cannot be generalized. .

Second, the mixed research method attempts to match the quantitative and qualitative data about the same topic. However, the artistic data from the biographical method were used for finding the meaning of feces as a qualitative method, whereas the scientific data from the experiments were used for verifying the possibility of the utilization of feces/urine in our society. Although these two approaches do not have the same topic, the respective results obtained are important, as they will be combined during the individual in-depth interviews as data for suggesting various opinions.

Lastly, the possibility exists of bias from arbitrary interpretation during the interview. The interaction between the interviewer and the interviewee is the characteristic of an interview. This interaction can facilitate obtaining detail information and personal opinions, reflecting the reason for the attitude of the interviewee to the research topic. However, the findings could be influenced by the interviewer's questions, which could be the weak point of the research method. Therefore, the results can be

obtained in the guideline, which was made from the interviewer. Nevertheless, the findings obtained from the interviews are important to understand and verify the perceptions on the interviewees on feces, because their perceptions can be expressed only by the interaction between the interviewer and the interviewee. The above explains why the qualitative method was chosen for the convergence of science and arts.

4.3 Scientific analytical research of feces with experiments

Generally, the negative perceptions on feces relate to odor, pathogenic bacteria, and the unpleasant appearance. However, feces have been used for composting for a long time, and livestock excreta are still being used in agriculture as fertilizer. Such negative perceptions increase the general indifference to the disposal of feces, as people simply want the unpleasant matter removed as soon as possible from their residential area. Consequently, the reality of feces has not been studied well, and only a few scientific researches have been conducted related to the medical and sanitation fields. In this study, various scientific experiments were conducted to investigate the reality of feces, namely, 1) soil characterization in terms of the humification degree and nutrient composition of the soil mixed with compost and bioreactor sludge, 2) the change in the ion composition of stored urine, and 3) the wastewater treatment results of the influent and effluent of constructed wetlands.

1) Samples and research targets
   - Compost characterization: commercial fertilizer, compost, bioreactor sludge, cow manure
   - Ion composition of urine: stored urine
   - Wastewater treatment systems: free-water surface constructed wetland and horizontal sub-surface constructed wetland

2) Analyzing instrument
   - Preparative HPLC
   - Pyrolysis GC/MS
   - Total organic carbon analyzer
   - Ion chromatography

3) Analysis factors
   - pH, humification index, ion concentration (ammonium, nitrate, nitrite, phosphate, calcium, magnesium, potassium, sulfate, and chloride), conductivity, TOC, TN, SUVA, biomolecular composition, and molecular size distribution

4.4 Biographical research of the artists who made their artworks with excreta

This relates to a biographical research study of the personal experiences identified in the course of the life of the subject. The major purpose of this methodology is to find the points of value from the accumulated individual experience during the life of the subject. Because experience in the past always links to the current life, the findings from the research enable the development of the present subject. This method focuses on the daily lives of the individuals, what they consider as important, and how to interpret their past [60]. Various materials were included in the study, such as diaries, letters, autobiographies, biographies, memoranda, and others. These different materials, which reflect individual characteristic, can be used to increase the reliability and validity of the research [61].

This research method enables determining the perceptions on the artists on feces, as reflected in their artwork. By understanding their opinion about feces, the results will be used as data during the interview to suggest various opinions to the interviewees. Biographical research was conducted on the two artists, Piero Manzoni and Kwon Chong-saeng, who were selected because they had created their artworks with excreta. However, the meaning of the artworks were different, with that of Piero Manzoni's attempting to explain the reality of artists and that of Kwon Chong-saeng attempting to show the purpose of life.

Piero Manzoni was an Italian avant-garde artist. In 1961, he exhibited an artwork consisting of 90 tin cans, titled *Artist's Shit*. On the label, the following sentence was printed, "Artist's Shit, contents: 30 grams net, freshly preserved, produced, and tinned in May 1961." The exhibition obviously caused a sensation. Kwon Chong-saeng is a children's storywriter. In 1996, he wrote a children's story titled *Doggy Poo*. Through the way to find the life purpose of a doggy poo, he gave that everything has the meaning of existence.

To this end, the following research questions are posed:

1) The research questions

- Where did they get inspiration for their ordinary artworks?

- What is the goal as an artist?

- Why did the artists use the excreta in their artworks?

4.5 Individual in-depth interview to apply the methodology of the convergence of science and arts

An in-depth interview is a qualitative research method that involves semi-structured interviews. In-depth characterization of the research topic can be conducted by the intensive interview between a respondent and an interviewer. The advantage of in-depth interviews is that they can interpret a research topic in a specific situation, meaning that information can be obtained in much more detail. However, certain limitations exist, such as a tendency to bias, not being generalizable, and the variability of the results depending on the interviewer's preparation for the conversation. The design of the interview process is important to minimize such disadvantages. Various interview techniques are available, but the general research method includes the interactive and relatively informal conversation, with a specific purpose. In particular, the characteristics of the questions (e.g., type, order, and intended purpose) should be considered carefully because they could influence the atmosphere of the conversation. The major purpose of this qualitative research method is to obtain a meaningful opinion from the respondent. The current study aims to find the changeable and the unchangeable factors about the existing perceptions on feces through employing this methodology. The artistic perceptions and the scientific results on feces will be provided to the interviewees. The aim is to repeat the interview approximately 10 times to monitor the changing perceptions. During the last interview, the changeable or unchangeable factors will be discussed with the interviewees.

1) Selecting the interviewees

Two criteria were employed in the selection process of interviewees, of which the first is project experience related to feces. As the interview will discuss feces, it is essential that the interviewee does not have a strong repulsion toward the subject. The second criterion is an understanding of scientific knowledge. The scientific data will be provided for convergence between science and arts; therefore, a person educated in science or engineering is needed to conduct the interview smoothly. The originality of the interview is that ordinary people, not representative persons, were selected as respondents. This approach was followed to suggest an alternative viewpoint for the research. Quantitative researches have used the statistical method, with people assuming that representative data can be obtained. However, the results could also indicate a tendency; therefore, the results might not match every case perfectly. This is the limitation of representativeness. To compensate for the lack of precision in the data, it is necessary to employ a qualitative method. Therefore, ordinary people were interviewed and their perceptions were investigated in depth in this study. The interview process followed the regulations of the Institutional Review Board (IRB). However, this research focuses on changing perceptions on feces during the interview; therefore, the risks or adverse effects to the interviewee are minimal. In addition, the questions and suggested materials are not included in the critical personal information area.

2) Research questions

The research questions comprise four major topics, which include several interview processes to derive detailed information from the interviewees. The topics are 1) the general perception of feces, 2) the meaning of feces from an artistic viewpoint, 3) scientific results on feces, 4) the changeable or unchangeable perceptions on feces.

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CHAPTER 5

Characterization of Feces / Urine, and Constructed wetland for greywater treatment

5.1 Introduction

This chapter focused on the scientific experimental results to provide the information about the utility of feces/urine and waterless toilet system. As a conventional sanitation system, the flush toilet has improved public health and protected human beings from waterborne diseases. However, industrialization and urbanization increased the amount of contaminant flow from the flush toilet. Existing wastewater treatment plants cannot afford to treat totally the contaminants because of the lack of treatment capacity. In particular, algal blooming and red tide problems are occurring in many countries, even in developed countries with well-established wastewater treatment systems. In addition, disturbed natural carbon cycle also has being accelerated. Nutrients in agriculture are based on the natural decomposition processes. When organisms such as animals and plants are decomposed, their debris left on the soil. From them, fertile soil can be maintained. However, the industrial agriculture system harvests every plant from the farms, so there was not any nutrients or humus. It causes the lack of humus and nutrients and forces to use chemical fertilizers. Human excreta was used an alternative fertilizer, but nowadays their utilities decreased. Even though they can be a stable nutrient sources for farming, the negative perception makes people avoid them. Therefore, some projects such as “Ecosan project,” “Reinvent the Toilet Challenge,” and “Science Walden” have started to investigate alternative toilet systems to reduce these environmental problems.

In this chapter, the scientific results about the fecal organic matter were provided to reveal the physico-chemical aspects which can help to improve human society. The applications and utilities of compost, urine, and constructed wetland were discussed in here. Three major experiments were conducted: 1) soil characterization in terms of humification degree and nutrient composition from the mixed soil with compost and bioreactor sludge, 2) ion composition change of storage urine and 3) wastewater treatment results of influent and effluent of the constructed wetlands.

From the experiments, the fertility of a compost by humification index was estimated with bio-molecular structure characterization and stable urine storage condition was optimized. In addition, efficiency of a constructed wetland for greywater treatment was verified.

5.2 Study methodology

5.2.1 Sample preparation

1) Soil sampling

Four types of soil samples were analyzed. One is commercial cultural soil. Second is mixed soil with commercial cultural soil and compost from waterless toilet. Third is mixed soil with commercial cultural soil and bioreactor sludge. Last one is the compost made from cow dung.

2) Urine sampling

Urine was used as fertilizer in the small village, but the sample was not collected because of apprehension of contamination. Instead of that, 2 L of urine sample was collected from six test persons. The samples were stored at the room temperature, then the transition of ionic composition was monitored during 62 days.

3) Water sampling from constructed wetland

This study investigates the contaminant removal efficiency and organic matter characteristics in free water surface constructed wetland (Boknae bio-park) in Korea. It located Boknae-ri, Boseong-gun, Jeollanam-do. To identify the contaminant removal efficiency, three sampling points were selected according to water flow: inflow, middle flow, and outflow point

4) Greywater sampling

The wastewater sample was taken from a constructed wetland in a small autonomous decentralized community, Namwon city, Jeollana-do, Korea (35°.43′S,127°.64′E). The greywater treatment efficiency was measured through influent and effluent of the constructed wetland. Sampling was performed once a month from July, 2012 to December, 2014. Samples were filtrated with 0.45 micro-filters (Mixed cellulose acetate, Advantech, Japan) and were stored at 4 ℃ for further analyses.

5.2.2 Preparative HPLC

A prep-HPLC system (JAI-LC-9201, JAI) with a handmade column was employed, along with a UV (UV detector 3702, JAI, Japan) and an RI detector (RI detector 50s, JAI, Japan). Two columns of different types were used to fractionate NOM samples. One is Toyopearl resin packed column (250 × 20 mm). Another is GS-310 (500 × 20 mm) which was manufactured in JAI. The separation principle of Toyopear column is a size exclusion chromatography, but GS-310 column has two

separation mechanisms which are a size exclusion and a hydrophobicity. The wavelength of the UV detector was 254 nm. The operating flow rate of the eluent was 2 mL/min. Phosphate buffer (2.4 mM sodium phosphate, 1.6 mM disodium hydrogen phosphate) was used as an eluent. 96 mM sodium chloride was also added into the eluent to increase the ion strength. The ion strength of every injected sample was also adjusted to about 10 μS/cm by adding sodium chloride. A gas-tight syringe was used to inject 5 mL samples. The column separation efficiency was calculated using polyetyleneglycols (PEGs: 400, 600, 1000, and 4600 MW).

Table 5.1 Experimental conditions of prep-HPLC

Model	JAI LC-9201
Standard solution	Polyetylenglycols (PEGs: 400,600,1000, and 4600 MW)
Flow rate	2 ml/min
Injection volume	5 ml
Column	Toyopearl column (20ø x 250)
Detector	UV detector (JAI UV 3072) and RI detector (JAI RI 50)
Eluent composition	3.5 mM sodium carbonate and 1.0 mM sodium bicarbonate

5.2.3 High-performance size exclusion chromatography (HPSEC)

The molecular weight distribution was measured by high-performance size exclusion chromatography (HPSEC). The equipped column (protein pak 125, Waters) works to make a different retention time depending on molecular weight. The eluent comprised 2.4 mM sodium phosphate, 1.6 mM disodium hydrogen phosphate, and 96.0 mM sodium chloride. The UVA (SPD-10AVP, Shimadzu) and fluorescence detectors (RF-10A XL, Shimadzu) were connected to the column. The flow rate of the eluent was 0.7 mL/min and the injection volume was 200 μL. Polystyrene sulfonates (PSSs: 210; 1.8, 4.6, 8, and 18 KDa) were used as standards for the molecular weight calibration curve. The experiment conditions are summarized in **Table 5.2**

Table 5.2 Experimental conditions of HPSEC

Flow rate	0.7 ml/min
Analysis time	25 min
Oven temperature	40℃
Injection volume	200 μl
Column	Protein pak 125, 7.8 × 300 mm, Waters
Detectors	UV wavelength at 254 nm
	Fluorescence wavelength at Ex=278 nm, Em=353nm
Eluent composition	96.0 mM sodium chloride
	2.4 mM sodium phosphate
	1.6 mM disodium hydrogen phosphate

5.2.4 Pyrolysis GC/MS system

A Curie-point pyrolyzer (JCI-22, JAI) was used for organic pyrolysis. Approximately 0.1 mg of sample was prepared in ferromagnetic foil (Profoil). The pyrolysis temperature was 590 ℃, and the volatilized compounds were injected into Agilent 7890A gas chromatography/mass spectrometry (5975C, Agilent). The DB-5MS (30 m, i.d. 0.25 mm, film thickness 0.50 μm) was used for separation, with helium as the carrier gas. The initial oven temperature was maintained at 40 ℃ and the final temperature was 300 ℃. The rate of the temperature rise was 7 ℃/min and the holding time at the final temperature was 10 min. The ion source was 210 ℃. The compounds were ionized at 70 eV and mass analyzed over a range of 30–500 amu.

5.2.5 Dissolved organic carbon concentration analysis

The dissolved organic carbon (DOC) analysis indicates a quantitative parameter of the organic matter. DOC was measured with a combustion method analyzer (TOC-V_{CPH}, Shimadzu, Japan), with a total nitrogen (TN) unit. The principle of the measurement is calculating the difference between the total carbon (TC) amount and the inorganic carbon (IC) amount in the sample. The samples were acidified before the organic carbon measurement with the addition of 2N hydrochloric acid. The acidified sample was sparged with air to remove the IC from the sample. When the sample is injected into the combustion tube, the organic carbons react with the oxygen at the temperature (720 ℃). The carbon dioxide that results from the reaction is measured as the total carbon amount by the non-dispersive

infrared (NDIR) detector. The TC standard solutions were made with potassium hydrogen phthalate. The concentration of the solutions were 1, 2, 5, 10, 25, and 50 mgC/L. The TN in the sample transformed to nitrogen monoxide when the sample was injected into the combustion tube and, subsequently, the gas was passed to a chemiluminescence gas analyzer. The nitrogen monoxide reacted with ozone, which generated nitrogen dioxide in the excited state. After the excited molecules released the energy to become stable, the TN concentration could be detected. Potassium nitrate was used as the TN standard solution, and the concentration of the solutions was the same as that of TC (unit: mgN/L).

5.2.6 Ion chromatography

Six cations (Li^+, Na^+, NH_4^+, K^+, Mg^{2+}, and Ca^{2+}) and seven anions (F^-, Cl^-, Br^-, PO_4^{3-}, NO_3^-, NO_2^-, and SO_4^{2-}) were measured by IC. The experimental conditions are summarized in **Table 5.3**.

Table 5.3 Experimental conditions of IC

	Anion measurement	Cation measurement
Model	ICS-90, Dionex	DX-120, Dionex
Standard solution	Seven anion standard II, Dionex	Six cation standard, Dionex
Flow rate	1.2 ml/min	1.0 ml/min
Analysis time	15 min	15 min
Injection volume	50 ㎕	50 ㎕
Column	IonPac® AS 14, 4 × 250 mm, Dionex	IonPac® CS 12A, 4 × 250 mm, Dionex
Detector	Conductivity detector	Conductivity detector
Eluent composition	3.5 mM sodium carbonate 1.0 mM sodium bicarbonate	20 mM methanesulfomic acid

5.3 Results

5.3.1 Compost characterization in terms of humification degree

One of the requirements of an effective organic fertilizer is maintaining soil fertility as long as possible. This condition requires slow degradation of the organic compounds in the compost. Humic matters are considered good fertilizers because they possess this characteristic. They are composed of aromatic compounds, which originate from indigenous plants and animal debris. Because of the generating process, humic matters are chemically stable and difficult to decompose by microorganisms compared with saccharide-based organic compounds. Humification is an index used to estimate the maturity of the organic matter. Various estimating methods have been used, such as the ratio of the absorbance at 465 nm to 665 nm (E_4/E_6 ratio), organic free-radical concentrations measured by electron spin resonance (ESR), nuclear magnetic resonance (NMR), and fluorescence spectroscopy [62]. However, these methods can only provide vague information about the organic matter because NOM is heterogeneous compounds. Therefore, it is difficult to identify the molecular characteristics by spectrometry, which uses the dynamics of energy. In this study, py-GC/MS analysis was conducted to obtain detail molecular information. The identified molecules were categorized into five groups, namely, polysaccharide, protein, polyhydroxy aromatics (PHA), lignin, and lipid. The humification of the samples was estimated indirectly by the ratio of PHA and lignin, and the effectiveness of each type of compost is discussed according to its molecular information.

1) Pyrolysis GC/MS results

The lignin content of cow manure compost was indicated as the highest. The lignin composes the secondary cell-walls in vascular plants. Its hydrophobic character can aid the transport of water [63]. As cows are herbivores, the high lignin content in their manure is linked to the diet of the animals. The lignin portions of the commercial organic fertilizer and the compost were similar, and the compost mixed with compost and sludge showed the lowest result. As regards polysaccharide, the results of the samples were similar. Polysaccharide is a polymeric carbohydrate molecule that exists in the cellulose or starch in a plant. It is used as a carbon source by microorganisms in nature; therefore, soil with high polysaccharide content is a good environment for growing them. Microorganisms can decompose the polysaccharide readily because of its molecular structure. This is probably the reason for the similar portions of polysaccharide in the samples, i.e., because of rapid decomposition during the composting process. However, if fertilizer has a high concentration of polysaccharide, it can be used for enhancing plant growth in a short time. Protein and lipid originate from the cells of microorganisms or metabolites; therefore, they can be indirect indicators

of the amount of microbial activity or mass. The sum of the portion between protein and lipid is shown in the following order: compost + sludge > compost > commercial soil > commercial organic fertilizer. The protein and lipid portions of the mixed sample with compost and sludge can be explained by the addition of microorganisms from the sludge. Because the sludge comes from the bioreactor, a large number of microorganisms could be present in the sample. Therefore, the portion in the mixed sample could be higher than that in the compost sample.

In view of the results of the molecular structure, the appropriate compost for improving soil fertility is the cow manure compost. It has a high portion of lignin and PHA and can therefore provide a stable energy source to microorganisms such as humic matters. Furthermore, as the commercial soil and compost showed similar biomolecular compositions, the compost could be an alternative fertilizer.

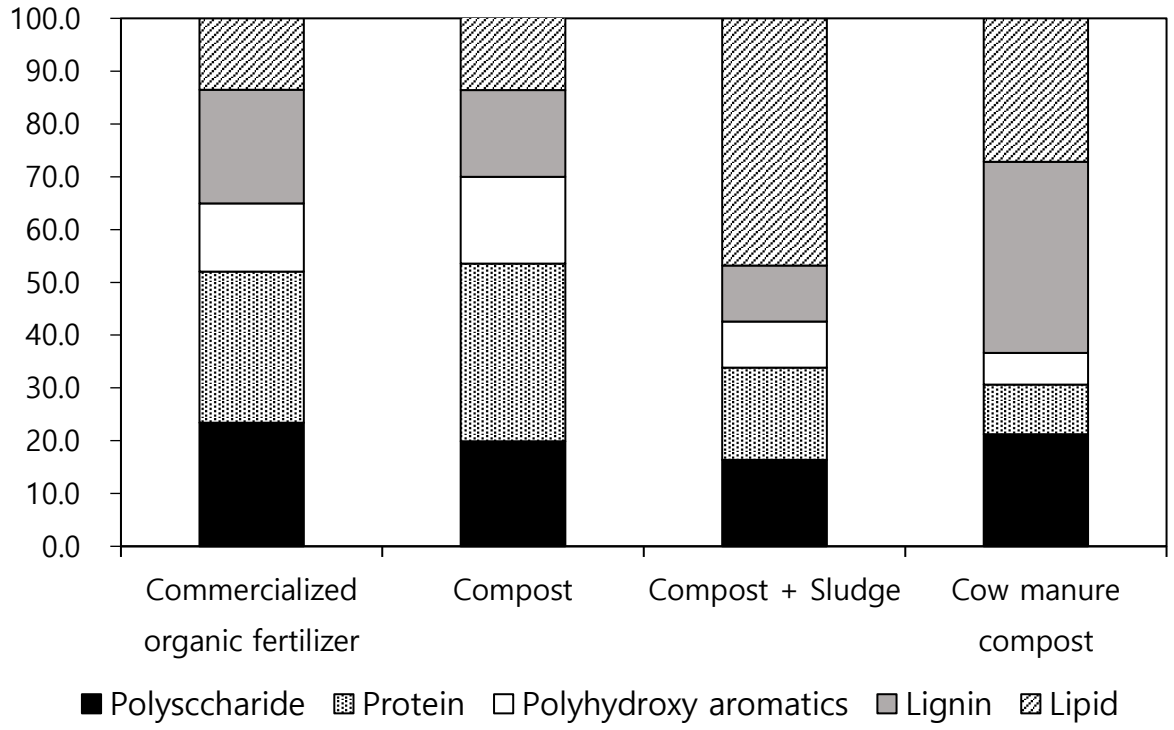


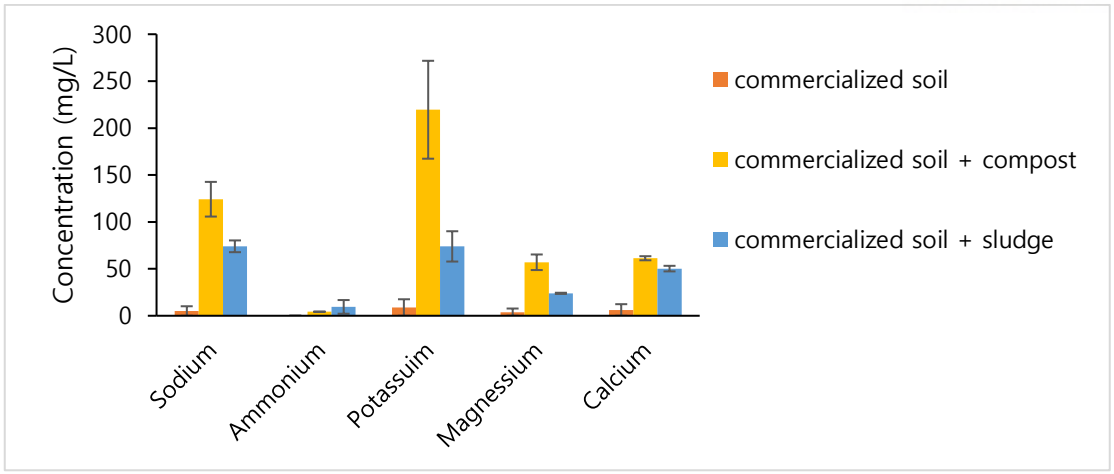
Figure 5.1 Biomolecular structures of fertilizers

5.3.2 Plant growth with nutrient composition from the mixed soil with compost and bioreactor sludge

Compost is the altered form of feces. Before the use of the flush toilet system, the composting toilet system played an important role in the agricultural community because it provided a good fertilizer. However, this type of compost has been replaced by chemical fertilizer. Subsequently, human feces have become simply contaminants. An experiment was conducted to compare the mineral nutrients in compost and commercial fertilizer in order to determine and reconsider the usefulness of feces. Three types of soil, namely, 1) commercial fertilizer, 2) soil mixed with commercial soil and compost, and 3) soil mixed with commercial cultured soil and bioreactor sludge were analyzed to determine the mineral nutrient composition and the plant growth in relation to the soils.

1) Nutrient composition

As indicated in **Figure 5.2(a, b)**, the soil mixed with compost showed the highest ion concentration of the detected species. Because potassium, nitrate, and phosphate are important nutrients for plant growth, a higher concentration of these components can be beneficial as fertilizers when compost is used. However, high concentrations of sodium and chloride affect plant growth adversely, as salinity is a negative effect factor. In this experiment, the mixed sample with commercial soil and compost had the highest NaCl concentration (124.1 mg/L sodium and 147.8 mg/L chloride). According to Tavakkoli et al., barley grows successfully in conditions under 200 mM NaCl (23 mg/L sodium and 35 mg/L chloride) [64]. In the current study, the measured NaCl concentration of the sample was higher than the reported concentration; therefore, the NaCl concentration in the sample can be considered a negative factor. The barley growth rate was actually affected, as indicated in **Figure 5.3**. Potassium and nitrate have been reported as important sources for optimal growth [65]. The ion concentrations in the soil mixed with commercial soil and compost (219 mg/L potassium and 584 mg/L nitrate) can therefore be advantageous as fertilizers. The overall measured ion species concentrations in the sludge mixed sample were lower than were those of the compost mixed sample, but higher than were those of the commercial soil sample (**Table 5.4**). This result could be attributed to the bioreactor source. The particular bioreactor was designed for methane production using food waste and human feces; therefore, the sludge could include the residuals from the feces. Since compost is also the altered form of feces, the ion species contents could be similar to those of compost. However, the concentrations could be different because the sludge contained food waste.



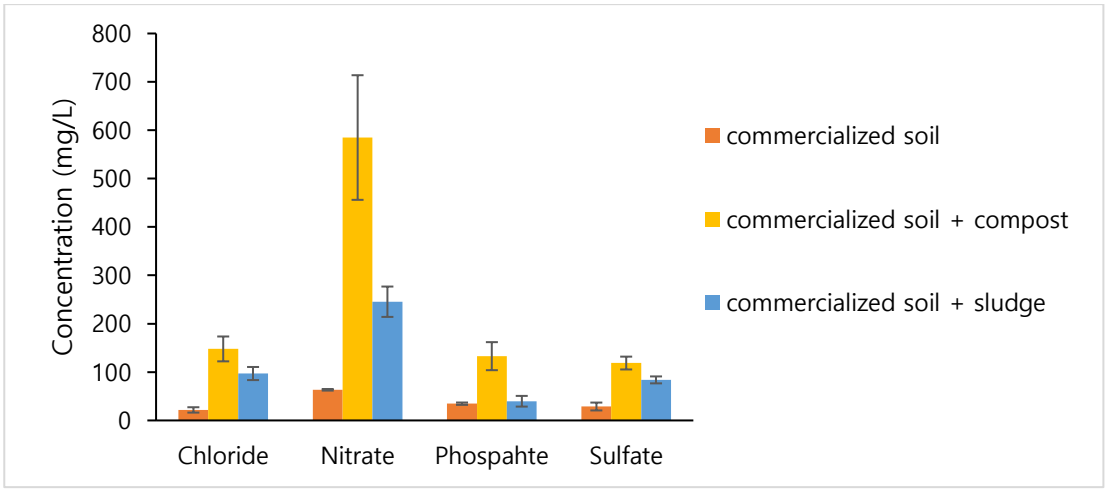


Figure 5.2 (a) Cation and (b) anion analysis results depending on samples

Table 5.4 Ion concentration of soil samples

	Sample name		
	Commercialized soil	Commercialized soil + compost	Commercialized soil + sludge
Sodium (mg/L)	31	124	74
Ammonium (mg/L)	0	4	9.5
Potassium (mg/L)	43	219.5	74
Magnesium (mg/L)	7.5	57	24
Calcium (mg/L)	13	61	50
Chloride (mg/L)	22	148	97
Nitrate (mg/L)	63.5	585	245.5
Phosphate (mg/L)	34	133	39.5
Sulfate (mg/L)	28.5	118.5	84

2) Plant growth and water conductivity

Plant growth rate was measured by estimating the length of the barley shoots. When comparing the shoot length, the soil mixed with the commercial soil and sludge showed the highest growth. Even though the compost mixed sample contained high nutrient concentrations, the barley shoots were the shortest. The conductivity measurement results appear to relate to the growth rate. The conductivity value shown in **Figure 5.3** is an indirect index to determine the salinity conditions. The results were from the extracted soil; therefore, the values might not match the in-situ soil conductivity value. However, the results can provide indirect information about the conductivity. The soil mixed with commercial soil and compost showed the highest value (approximately 2 000 μS/cm). The salinity classes of Richards [66], indicate that conductivity below 2 000 μS/cm affects only sensitive plants like beans. Moreover, barley is reportedly tolerant to high salinity. In this experiment, the composted sample showed a conductivity value of approximately 2 000 μS/cm, with the crop being barley. The salinity classes of Richards indicate that this factor would probably not affect plant growth detrimentally. However, additional study is required to explain the unexpected results. Humic substances, heavy metal concentrations, or microbial communities in the soil could be the appropriate topics for such study.

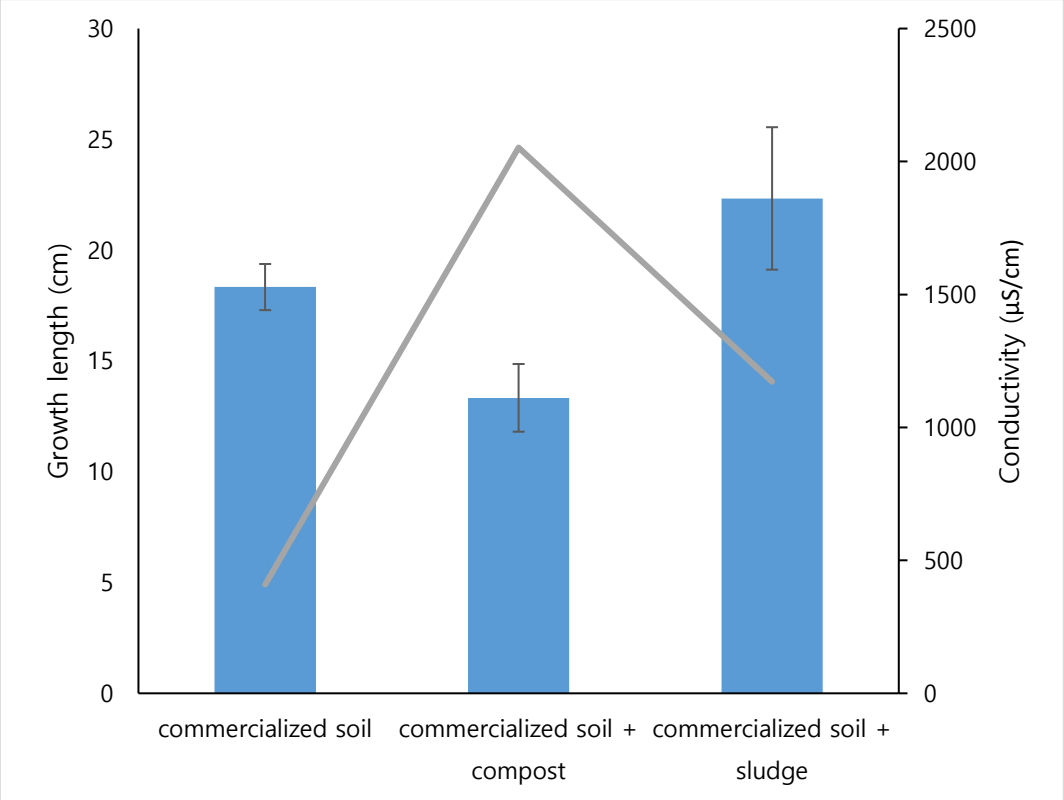


Figure 5.3 Plant growth and conductivity

5.3.3 Ion composition change of storage urine

In the waterless toilet system, the storage of urine are important issues because the urine has to be collected from the toilet. Blockages and unpleasant odor are major problems in the collection of urine; however, the usage of the urine as liquid fertilizer because of the high concentration of nutrients is a benefit of the system. Several studies have reported the utilization of urine as liquid fertilizer, but the focus was mostly on the final ion composition of stored urine, and not on that of the fresh urine. The change in the ion composition of urine from the fresh to the decomposed urine is an important factor, as it provides information for managing the storage of urine. In this study, the ion composition of urine was monitored for 62 days in terms of ammonium, nitrate, nitrite, phosphate, sulfate, calcium, magnesium, chloride, and sodium. The total organic carbons and total nitrogen concentration were also measured during the experimental period.

1) Overall ion composition of urine

Urine contains 85% nitrogen compound as urea; however, the concentration decreases over time when the urine is stored. The decrease occurs because of the urease-active bacteria that enables the hydrolysis of the urea, which changes the ion composition and facilitates an increase in pH and the precipitation of salt. The overall reaction can be explained by the following chemical reaction equation.

$$NH_2(CO)NH_2 + 2H_2O \rightarrow NH_3 + NH_4^+ + HCO_3^-$$

Because of the presence of ammonia, pH increases, and, subsequently, the salt precipitation increases [67]. A report by Udert et al. (2003) describes urea hydrolysis and precipitation dynamics in a urine-collecting system [68]. The authors reported the ionic composition of fresh urine and stored urine, which had a retention time of at least three weeks. The experimental period for urea depletion was only 0.5 days with urease-active bacteria. In the current study, the ionic compositions of fresh urine and stored urine (retention time of 62 days) were analyzed. A comparison of the results on the ion concentration in the current study and the reported results [68] is shown in **Table 5.5**. The concentration of each ion species in fresh urine was different, as it is influenced by personal diet. The urea concentration was not measured in the current study; however, from the total nitrogen concentration it can be inferred that urea constitutes a major portion of the nitrogen composition in fresh urine. Rapidly decreasing ion concentrations in the stored urine were not indicated in the current study, even though the retention time was much longer than that of the reported experiment. This result can be ascribed to the lack of activity in the urea-active bacteria.

The reason for this result could be that the urine was stored in a sterile sample bottle at room temperature, even though the urea-active bacteria are ubiquitous and are present even in the human body.

In addition, fresh urine without bacteria was used in the current experiment, whereas Udert et al. used a sample with cultivated bacteria. The slightly decreasing total nitrogen concentration and the low level of ammonia generation indicated that urea-hydrolysis was not occurring actively in the current study. The different ion concentrations in the stored urine could be ascribed probably to the different experimental conditions.

Table 5.5 Measured urine ion concentrations

	Fresh urine		Stored urine	
	Udert *et al*	Experimental results	Udert *et al*	Experimental results (after 62 days)
Total organic carbons (g C m^{-3})	-	5444	-	4943
Total nitrogen (g N m^{-3})	-	6766	-	5843
Urea (g N m^{-3})	5810	-	73	-
Ammonia (g N m^{-3})	254	463 (mg/L)	1720	462
Nitrate (g N m^{-3})	-	44		2
Nitrite (g N m^{-3})	-	0		68
Phosphate (g P m^{-3})	367	384	76	336
Calcium (g m^{-3})	129	52	28	8
Magnesium (g m^{-3})	77	135	1	59
Potassium (g m^{-3})	2670	1816	770	1530
Sulfate (g SO_4 m^{-3})	748	1135	292	1034
Chloride (g m^{-3})	3830	4628	1400	4978
Conductivity (mS/cm)	-	18	-	18
pH	7.2	6.6	9.0	7.5

2) Nutrient concentration monitoring results

Nitrogen (N), phosphorus (P), and potassium (K) are the major compounds in urine, which make human urine a good fertilizer for plants. The total nitrogen, nitrate, nitrite, and ammonium concentrations were measured to determine nitrogen transition. In addition, the P and K concentrations were estimated over the monitoring period.

The total nitrogen concentration in the stored urine decreased by approximately 10 % compared with that of the fresh urine **(Figure 5.4**). The result can be explained by urea-hydrolysis not occurring actively in the urine used in the current study. Because the final product of urea-hydrolysis is ammonia gas and ammonium ion, large amounts of nitrogen can be lost. However, in the current study, the ammonium ion concentration did not increase rapidly and the total nitrogen concentration did not decrease. The denitrification was verified by monitoring the nitrate and nitrite concentrations (**Figures 5.5 and 5.6**). The nitrate concentration decreased over time and finally dropped to almost zero. On the other hand, the nitrite concentration increased from zero to 62 g N m^{-3} (median value). The denitrification process is performed by anaerobic heterotrophs in anoxic condition: nitrate (NO_3^-) → nitrite (NO_2^-). Although the nitrogen in urine is reduced by denitrification and ureolysis, large amounts of the ammonium ion can be a useful nutrient. This is because most plants use ammonium as a nitrogen nutrient in assimilation [69], therefore, stored urine can help the growth of plants. The ammonium produced from urea is well known as a nitrogen nutrient source in urine. However, the current study did not detect a large amount of ammonium produced from urea-hydrolysis owing to the lack of urease-active bacteria.

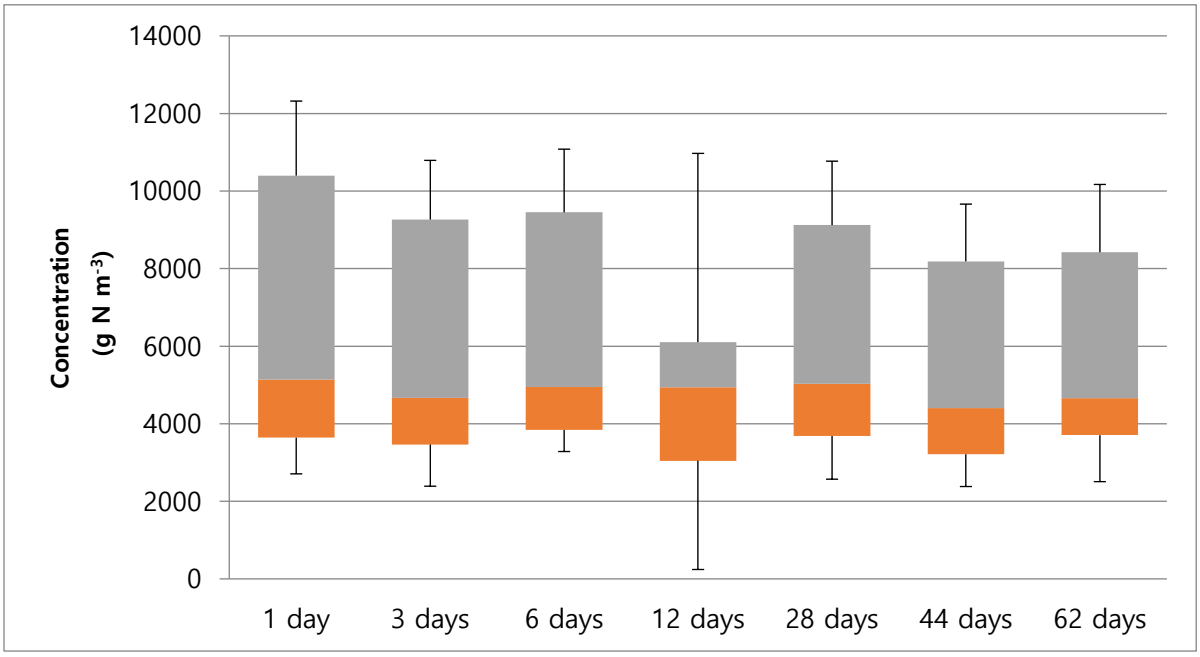


Figure 5.4 Total nitrogen concentration

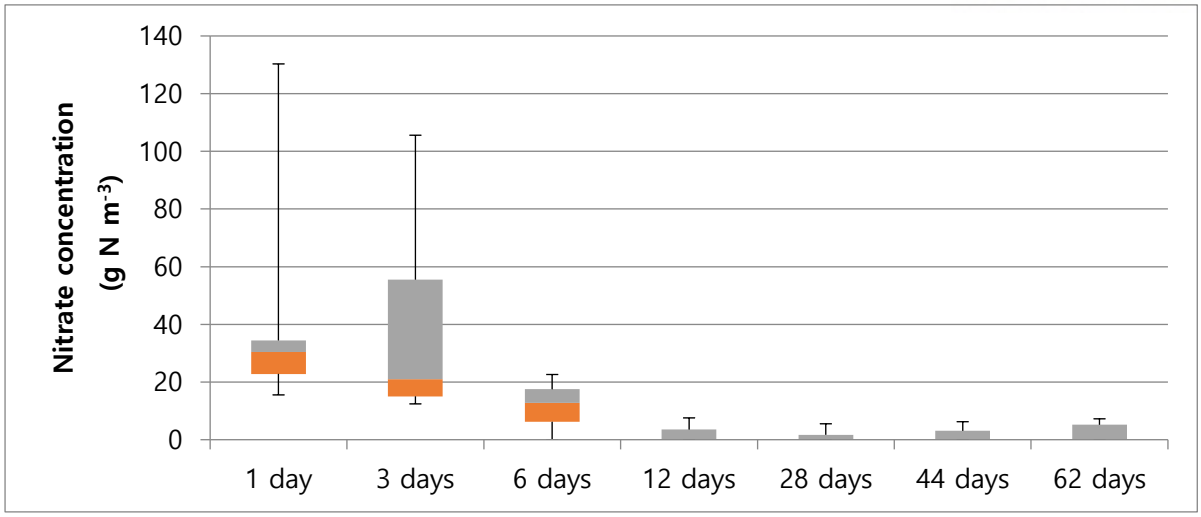


Figure 5.5 Nitrate concentration

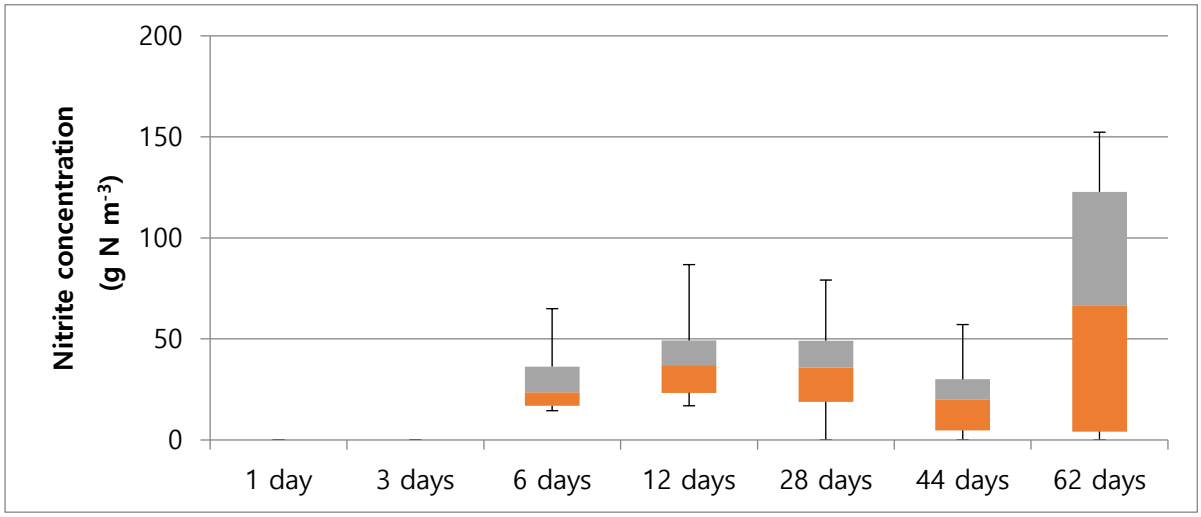


Figure 5.6 Nitrite concentration

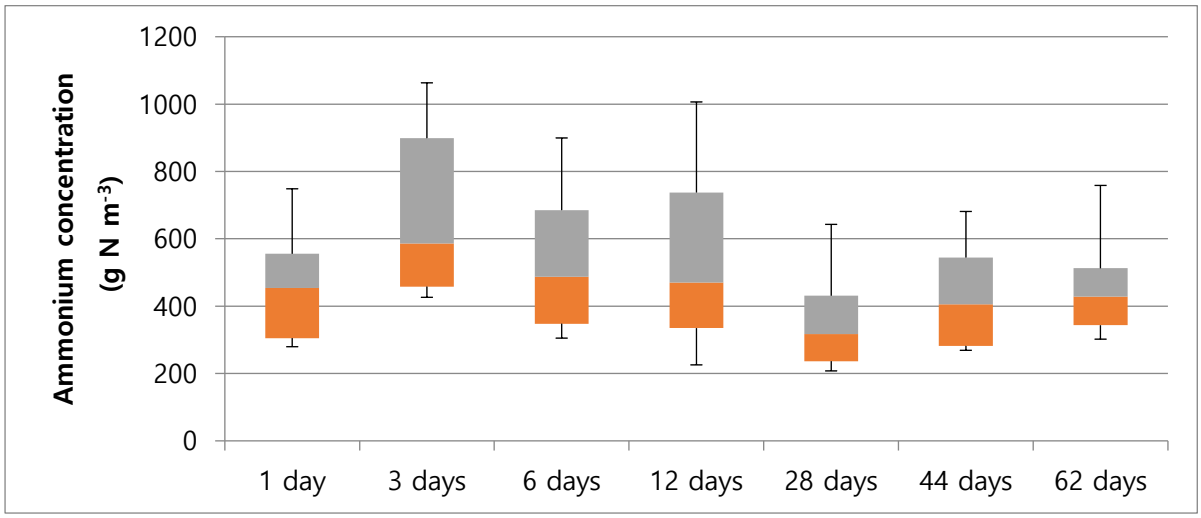


Figure 5.7 Ammonium concentration

Other important nutrients in plants are P and K. Generally, phosphorus exists in stored urine as precipitates, such as hydroxyapatite ($Ca_{10}(PO_4)_6(OH)_2$) and struvite ($MgN_4PO_4 \cdot 6H_2O$). The reactions are caused by the chemical complexation between Ca, Mg, and phosphate. The precipitation is accelerated when the pH increases by hydrolysis. The study by Udert et al. [68] reported decreasing ion concentrations of Ca, Mg, and phosphate in the stored urine. However, the current study did not detect different concentrations of the ion species between the fresh and the stored urine because there was no hydrolysis reaction (**Figures 5.8**, **5.9**, and **5.10**). Calcium and magnesium ion concentrations were provided until 28 days because the rest of the values could lead to confusion. Both ion concentrations were almost zero in 44 days, but at 62 days the calcium concentration was 50 g Ca^{2+} m^{-3} and the magnesium concentration was 60 g Mg^{2+} m^{-3}.

Potassium is an important nutrient associated with the ATP (adenosine triphosphate) process in the plant metabolite. Fresh urine has soluble potassium that the potassium ion uses directly. Generally, stored urine has a low concentration of potassium ion because soluble potassium changes into insoluble precipitates such as potassium struvite. However, in the current study, no change was indicated in the potassium concentration between the fresh and the stored urine because there was no hydrolysis reaction (**Figure 5.11**).

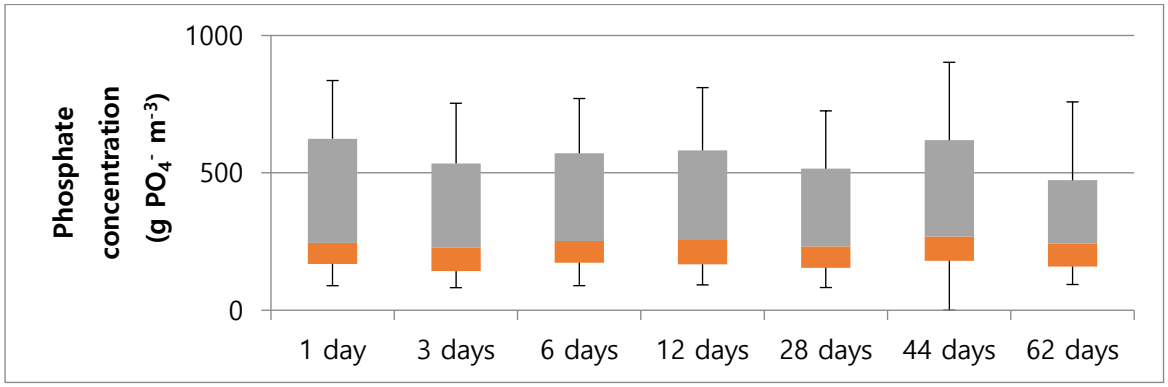


Figure 5.8 Phosphate concentration

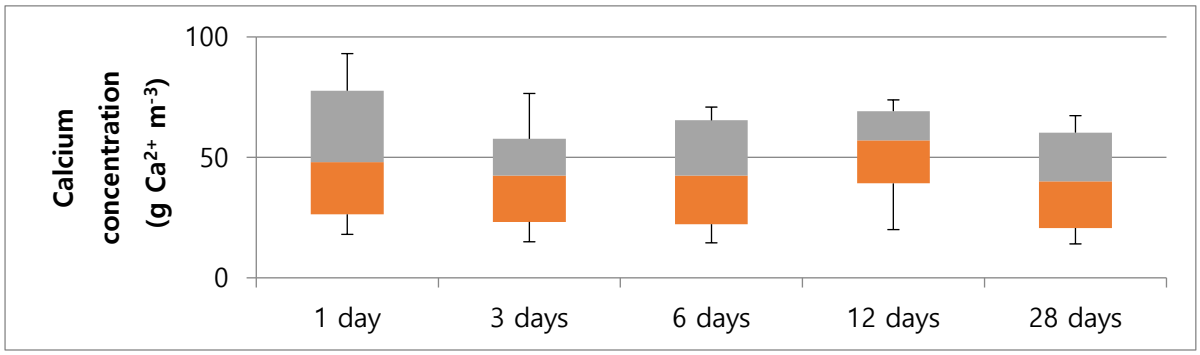


Figure 5.9 Calcium concentration

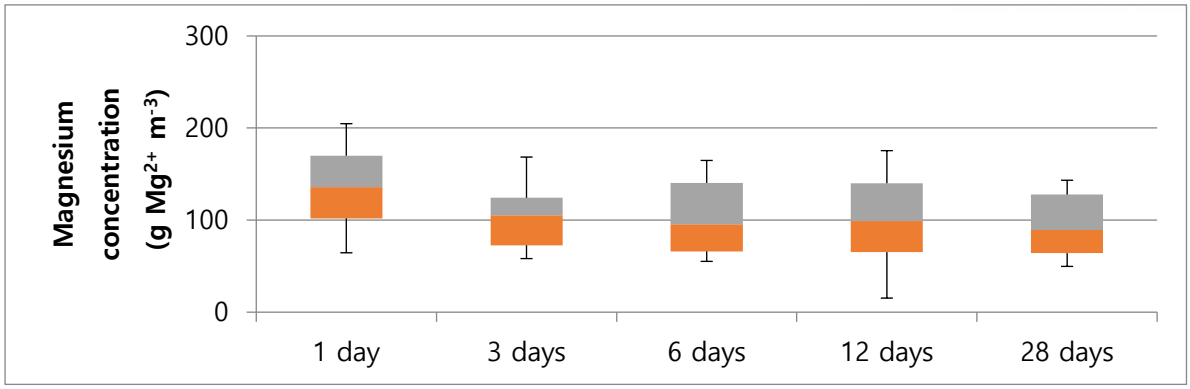


Figure 5.10 Magnesium concentration

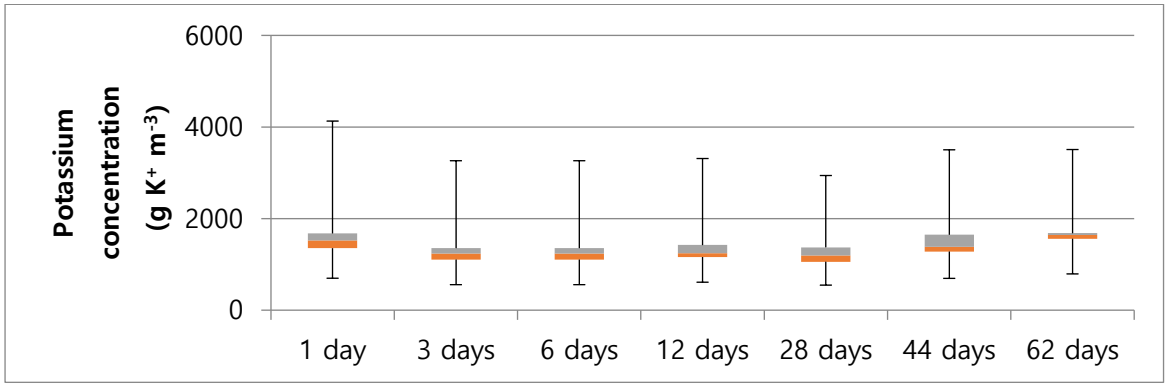


Figure 5.11 Potassium concentration

3) Monitoring results of other chemical conditions in terms of TOC and pH

Urine has various organic compounds such as urea, vitamins, and decompositions from the diet. Organic carbons can be decomposed by assimilation of microbial activities, but in the current study, the concentration of TOC did not decrease (**Figure 5.12**). This result can be explained by the storage condition of the urine, i.e., stored in a sterile sample bottle with a cap, minimizing microbial cultivation. Consequently, the decomposition of organic matter and hydrolysis of urea did not occur actively. The pH of urine changes from neutral (approximately 7) to the alkali condition (approximately 9) because of urea hydrolysis. The pH can increase rapidly up to 9 in 0.2 days with urease-active bacteria [68]. In the current study, however, the pH increased slightly over 52 days (**Figure 5.13**). This result could be ascribed to the inactive ureolysis.

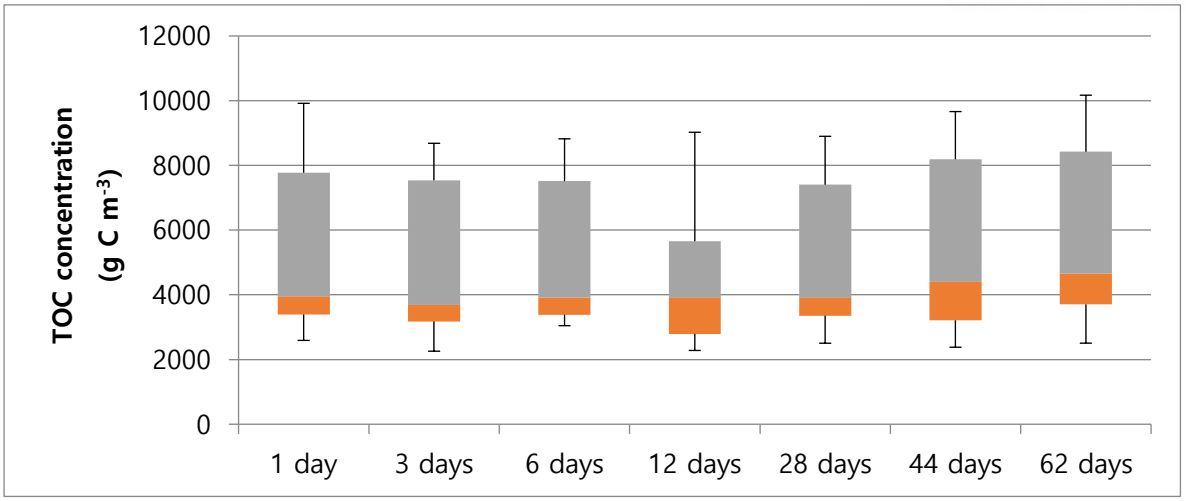


Figure 5.12 Total organic carbon concentration

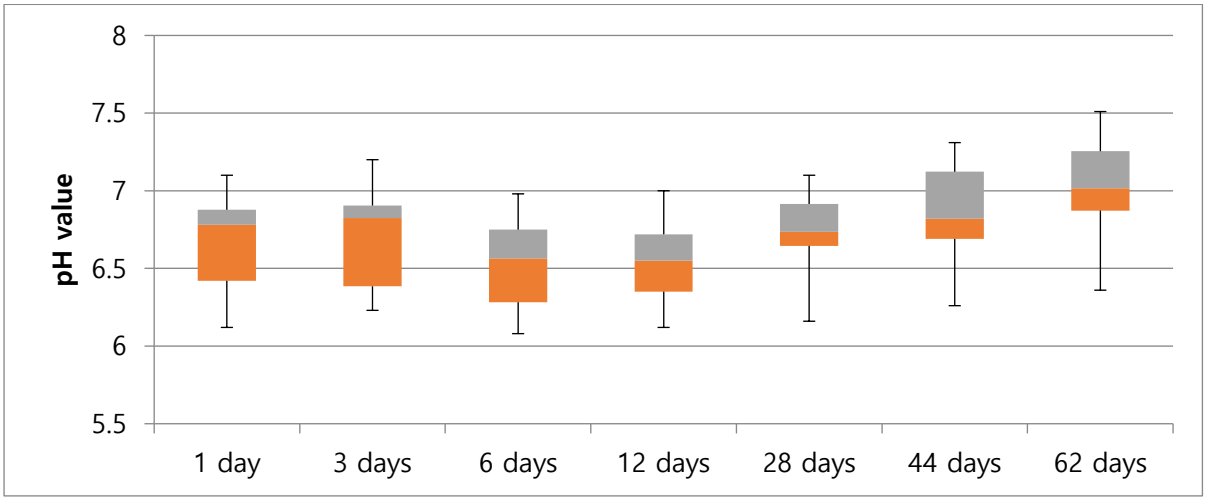


Figure 5.13 Monitoring of pH value in fresh urine

5.3.4 Wastewater treatment results of influent and effluent of the constructed wetlands

Constructed wetlands are good alternative water treatment processes to reuse wastewater, as their maintenance costs and energy consumption are low. This system is based on ecological treatment processes, such as the uptake by plants, sedimentation, precipitation, adsorption, microbial activity, and physicochemical reaction. Several studies on the removal of contaminants from wastewater by constructed wetlands showed a high level of treatment efficiency, i.e., 80 % removal of phosphorus, 58–68 % removal of nitrogen, and 67–90 % removal of BOD_5 [70, 71]. In this part, two types of constructed wetlands were introduced to suggest the utility of constructed wetland in urban community as a wastewater treatment system.

5.3.4.1 Free water surface constructed wetland (Boknae bio-park constructed wetlands)

The free-water surface constructed wetland comprises several flooded planted ponds, floating plant pond, submerged plant pond, and emergent plant pond. Following the water flow, contaminants are removed by biological, chemical, and physical mechanisms, e.g., settling, adsorption, microbial activity, and photo-degradation. In addition, the constructed wetland can provide a habitat for animals and a place of recreation for people. Moreover, a major advantage of this system is the low operation cost, as the water flow is governed by gravity. However, some of the requirements could be considered disadvantages, such as a large land area, supervision of seasonal harvesting, and a warm climate. This study investigates the contaminant removal efficiency and organic matter characteristics in a free-water surface constructed wetland (Boknae bio-park) in Korea. This constructed wetland treats the effluent from a wastewater treatment plant. The land area is 13,655 m^2, the daily treatment capacity is 300 m^3/day, and the hydraulic retention time is seven days. Three sampling points were selected in accordance with the water flow to identify the contaminant removal efficiency, namely, the inflow, middle flow, and outflow points (**Figure 5.14**).

Figure 5.14 Sampling points in the free water surface constructed wetland

1) Total nitrogen (TN) and dissolved organic carbon (DOC) concentrations

The TN concentration decreased and the DOC concentration increased in accordance with the water flow (**Figure 5.15**). At the inflow point, 1.69 mg N/L of TN was reduced to 0.55 mg N/L, ascribed to the denitrification and plant uptake process in the constructed wetland. The nitrogen species in the TN were defined as nitrate and nitrite (**Figure 5.16**). Vymazal [72] has reported that the free-water surface constructed wetland showed relatively medium denitrification compared with other types of constructed wetlands. In addition, as plants prefer nitrate as a nitrogen nutrient,

a reduction could occur in the nitrate concentration. However, the DOC concentration increased with the water flow, which is related to the plants in the constructed wetland. Submerged plants or floating plants are planted in free-water surface constructed wetlands. The life cycle of the plants ends when they decompose in the water, with their debris generating organic matters. In this way, the DOC concentration can increase. Seasonal harvesting is therefore required as a reduction of DOC in free-water surface constructed wetlands.

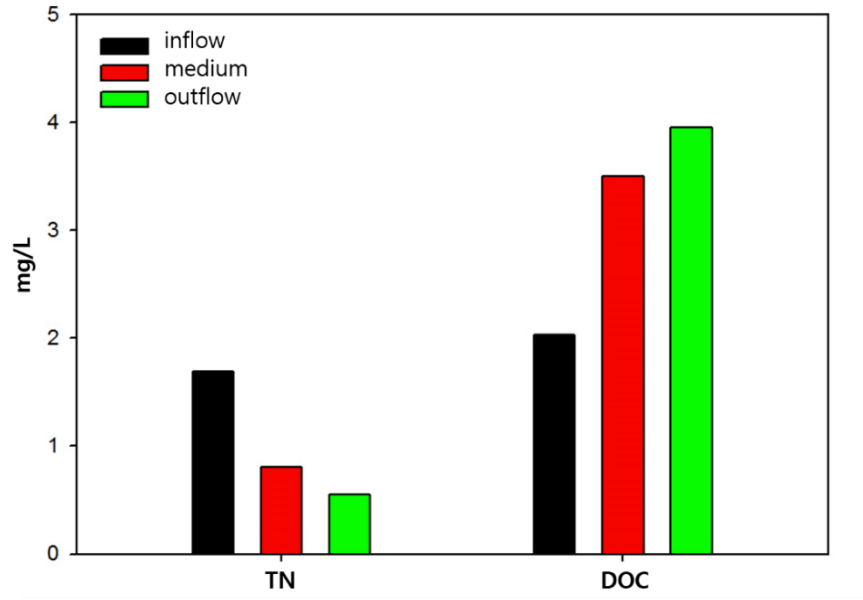


Figure 5.15 TN and DOC concentration depending on sampling sites

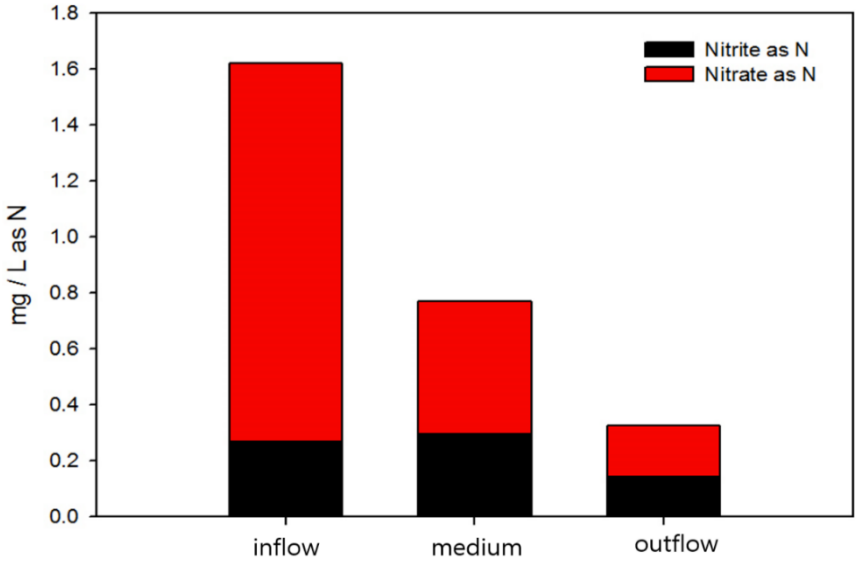


Figure 5.16 nitrate and nitrite concentration depending on sampling sites

Table 5.6 DOC, TN, and nitrogen species concentration

	DOC (mg/L)	TN (mg/L)	NO_2^- as N (mg/L)	NO_3^- as N (mg/L)
Inflow	2.03	1.69	0.27	1.35
Medium	3.50	0.81	0.29	0.48
Outflow	3.95	0.55	0.14	0.18

2) Dissolved organic matter (DOM) characterization by SUVA and py-GC/MS

The SUVA value is an indicator to estimate the hydrophobicity of the dissolved organic matter in a water sample. A high value indicates that the DOM comprises hydrophobic compounds such as polyhydroxy aromatics (PHA). In this study, the SUVA value of the inflow sample was the highest among the samples. The value between 2 and 4 indicates that the DOM comprises a mixture of hydrophobic and hydrophilic organic matter (inflow SUVA: 2.67, medium SUVA: 2.31, and outflow SUVA: 2.27) (**Table 5.7**).

The biomolecular compositions of the three samples were categorized in six groups, namely, polysaccharide (PS), amino sugar (AS), protein, polyhydroxy aromatic compounds (PHA), lignin, and lipid. The inflow sample showed the highest portion of lipid (**Figure 5.18**), because it originated from the wastewater treatment plant effluent and possibly contained the debris of microorganisms, which could be a source of lipids. The results from the medium and outflow samples showed similar molecular compositions and, in comparison with the inflow sample, the PHA and protein portions were large. This result can be described by polymerization. According to Steinberg and Muenster [73], polyphenols such as lignin are important monomers that can be accelerated by the presence of transition metals, clays, and amino acids and sugars. An alternative polymerization model was proposed by Harvey and Boran [74], as the free radicals in unsaturated lipids could form cross-links. From these suggested models, the decreasing of the lipid and lignin portions and the increasing PHA portion can be explained. In the inflow sample, polymerization with lipid and lignin occurred, after which PHA was generated by the reaction in the medium sample. In addition, the PHA portion of the outflow sample was larger than were any of the others. This result could be related to polymerization by amino sugars. As PS can be produced by microorganisms and decomposing plants or microbial residues, it increased with the water flow.

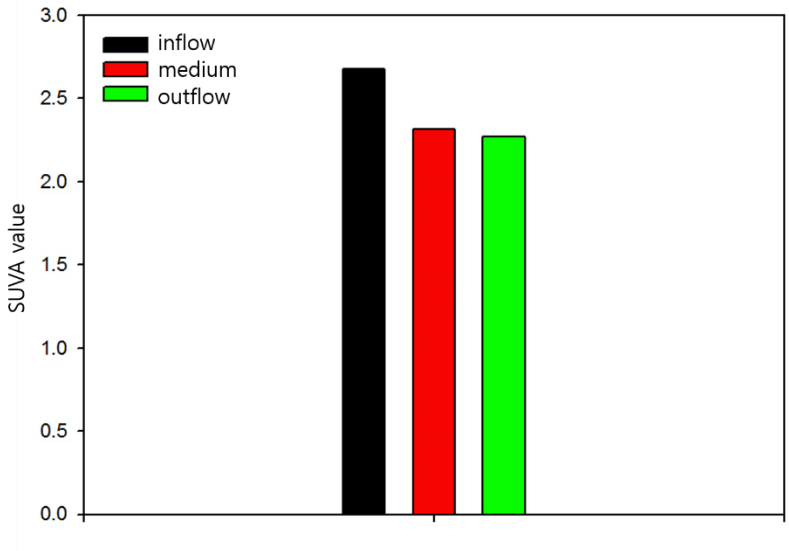


Figure 5.17 Calculated SUVA value depending on sampling sites

Table 5.7 DOC, UV absorbance, and SUVA values according to sampling sites

	DOC (mg/L)	UV absorbance (254nm)	SUVA
Inflow	2.03	0.054	2.67
Medium	3.50	0.081	2.31
Outflow	3.95	0.090	2.27

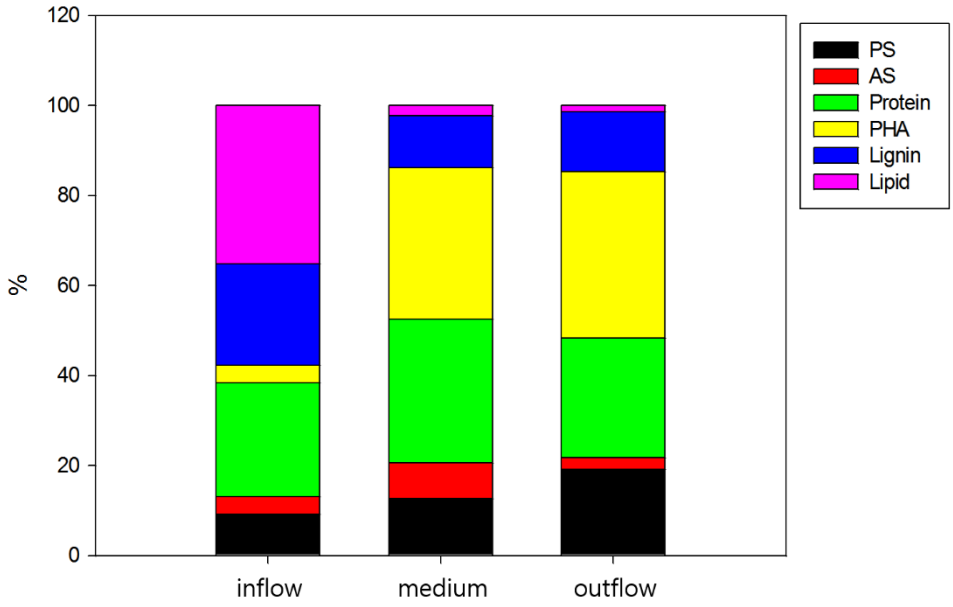


Figure 5.18 Biomolecular compositions depending on sampling sites

3) Biopolymer characterization according to molecular size

The SEC and preparative HPLC were used to characterize DOM in the wetland. The size distribution results showed that the DOM concentration increased and that high-weight molecules were generated with the water flow (**Figure 5.19**). The Y-axis relates to the concentration; therefore, the high UV response in the outflow indicates the increasing DOM concentration. These results correlate with the measured results of TOC, depending on the sampling sites (**Table 5.7**). The appearance of high-weight molecules can be described by polymerization, as was mentioned in the previous section (Dissolved organic matter characterization by SUVA and py-GC/MS). In addition, the increase in PHA indicated by the py-GC/MS results could explain the increase in the high-weight molecules, depending on the sampling sites.

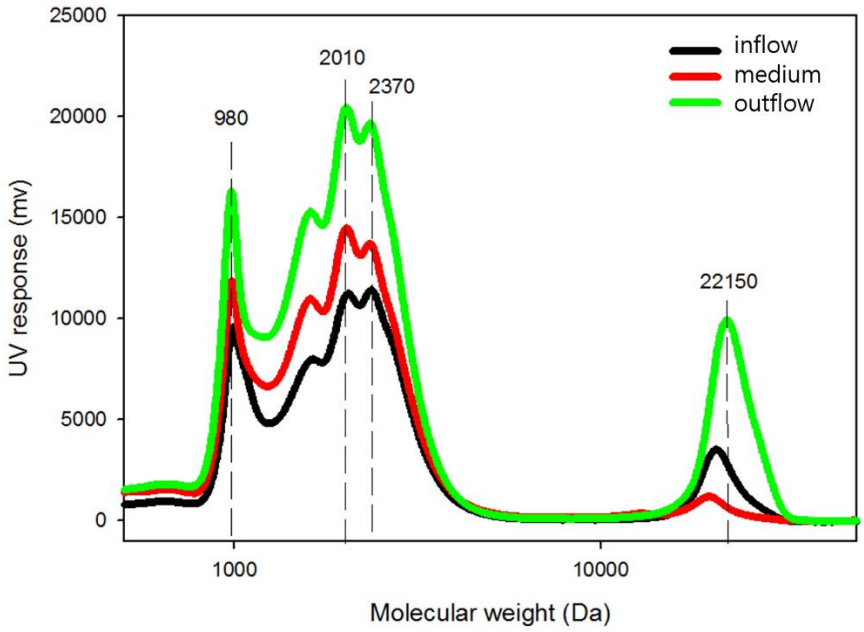


Figure 5.19 Molecular size distributions depending to the sampling sites

A preparative HPLC system was used to fractionate the molecular samples, depending on hydrophobicity and size. The column used in the study can separate the injected samples according to these two characteristics, but it has a limitation that two separation mechanisms occur to sample simultaneously, as the particular separation reason is unclear. Consequently, the chromatograms of the SEC and preparative HPLC differed. **Figure 5.29** shows the chromatograms from the preparative HPLC system. In the results, the inflow and medium samples had three peaks in the RI and UV detectors, but the outflow sample had only one peak. These results indicate that transformation of the molecular characteristics had occurred in the constructed wetland, with each peak having different molecular compositions. In the inflow sample, the first peak only had a lipid

portion, and the third peak showed a large portion of lignin. Lignin is known as a hydrophobic and large molecule. Since the peak detection time relates to size and hydrophobicity, an increase was indicated in the portion of lignin. Lipid appears to be affected by molecular size, which is derived from proteins. In the instance of the medium sample, three peaks showed large portions of PS and amino sugar. The increase in these biomolecules is ascribed to their originating from the decomposition of microorganisms and plants. However, the difference in biomolecular composition between the total (**Figure 5.18**) and fractions (**Figure 5.20**) was still unusual. Several sample analyses by py-GC/MS could therefore be needed. In the outflow sample, only one peak was shown, which was similar to the total biomolecular composition (**Figure 5.20**). According to these results from the inflow to the outflow, the transformation of biomolecular can be investigated that decreasing lipid and increasing PHA. The results showed the humidification of DOM by the treatment in the constructed wetland.

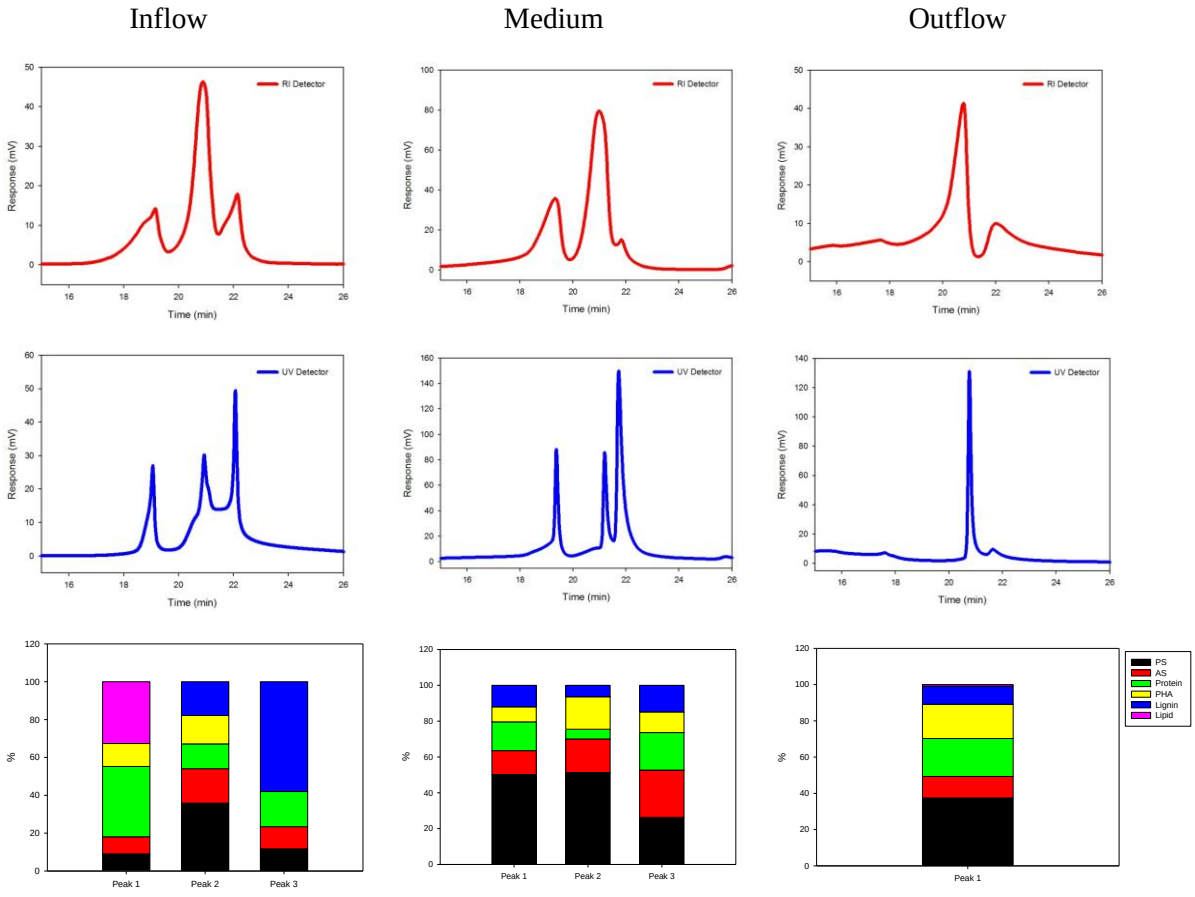


Figure 5.20 chromatograms from preparative HPLC and biomolecular compositions in fractions depending to the sampling sites

5.3.4.2 Horizontal sub-surface constructed wetland (Small village constructed wetlands)

The horizontal sub-surface constructed wetland is the most widely used constructed wetland type in Europe. It is designed to treat wastewater by filtration, microbial activities, and plant growth. The general wetland shape is rectangular, with a planted medium bed layer. In passing through the medium bed, the wastewater is treated in aerobic and anoxic conditions. This type of constructed wetland does not have surface water, avoiding the problem of mosquitos, which breed in the free-water surface type wetland. In addition, the area required for treatment is smaller than is that of the free-water surface type wetland. However, it takes time for the microbial inoculant to develop, and pretreatment could be required to prevent clogging. The constructed wetland used in this study is located in a small autonomous decentralized community, Namwon city, in Korea. The community was established in 2010 and covers an area of 26 360 m^2. The population is approximately 200. The households use a dry-composting ecological toilet system to reduce wastewater, and their greywater from the kitchen and bathroom flow into the constructed wetland. The treatment capacity of the constructed wetland is 15 m^3/d. The influent and effluent of the constructed wetland were analyzed to identify the contaminant removal efficiency.

Figure 5.21 Constructed wetland in the autonomous decentralized community, Namwon city, Jeollana-do, Korea

1) Monitoring results about water characteristics of influent and effluent from constructed wetland

The water characteristics of the influent and effluent samples are summarized in **Figure 5.22**. As the samples measured were taken from the wastewater from households, some variations occurred depending on the season and personal events in the village. The median value of DOC in the influent was 13.8 mg C/L, but the maximum and minimum values were 67.4 and 5.9 mg C/L, respectively.

The TN concentration showed similar patterns (median: 7.6, maximum: 35.4, and minimum: 1.7). The ammonium ion was detected only as one of the nitrogen species, and probably originated from bathroom water, as the influent is greywater. Normally, ammonium is the first nitrogen species to appear when organic nitrogen is decomposed and it is therefore detected widely in wastewater. The sodium and chloride ion concentrations were measured to check the removal efficiency of salt, as greywater contains water from the kitchen and salt is commonly used in cooking. The high concentration of salt in water could have a negative effect on the aquatic environment if not treated properly. The chloride concentration was estimated at 8.5 to 37.5 mg/L (median: 14.1) and the sodium concentration ranged from 10.3 to 52.0 mg/L (median: 27.0). In domestic wastewater, the chloride concentration reportedly ranges between 48 and 506 mg/L and the sodium concentration between 26 and 318 mg/L [75]. A comparison between the data of this study and the reported data appears to confirm that greywater contains a lower concentration of salts. This particular constructed wetland removed 80% of DOC. The median value of the measured DOC in the effluent was 2.4 mg C/L. This value is lower than is the average DOC value (3 mg C/L) in Korean rivers. The chloride and sodium ion concentrations were measured to verify the salinity of the reclaimed water; however, no significant difference was found between the influent and effluent. The ammonium nitrogen in the influent changed into nitrate nitrogen through the constructed wetland. This nitrification could relate to the microbial activity in the constructed wetland. Therefore, the high contaminant removal efficiency of the constructed wetland was verified in relation to the DOC and ammonium contents.

This small village uses upstream valley water as drinking water. The used water flows to the constructed wetland and the treated water is discharged into the downstream valley. This water flow system is a good example of wastewater flow in an urban area. Water samples were obtained from different sites for analysis (**Figure 5.23**). The monitoring period was July 2010 to December 2014 and the total sampling numbers were 19th (**Figure 5.24**). Because of unexpected research schedules, monthly sampling could not be conducted; however, the seasonal effects were shown by time-series analysis. The DOC concentrations in the drinking water were below 1 mg C/L during the monitoring period, but it increased to 70 mg C/L because of human activities. The constructed wetland reduced the DOC concentration by 80%, with the effluent showing a normal 2–3 mg C/L DOC concentration. However, this was higher than was the concentration of the downstream valley water, but most of the measured values showed a difference below 1 mg C/L. These results indicate the applicability of the constructed wetland as an alternative wastewater treatment system in urban areas.

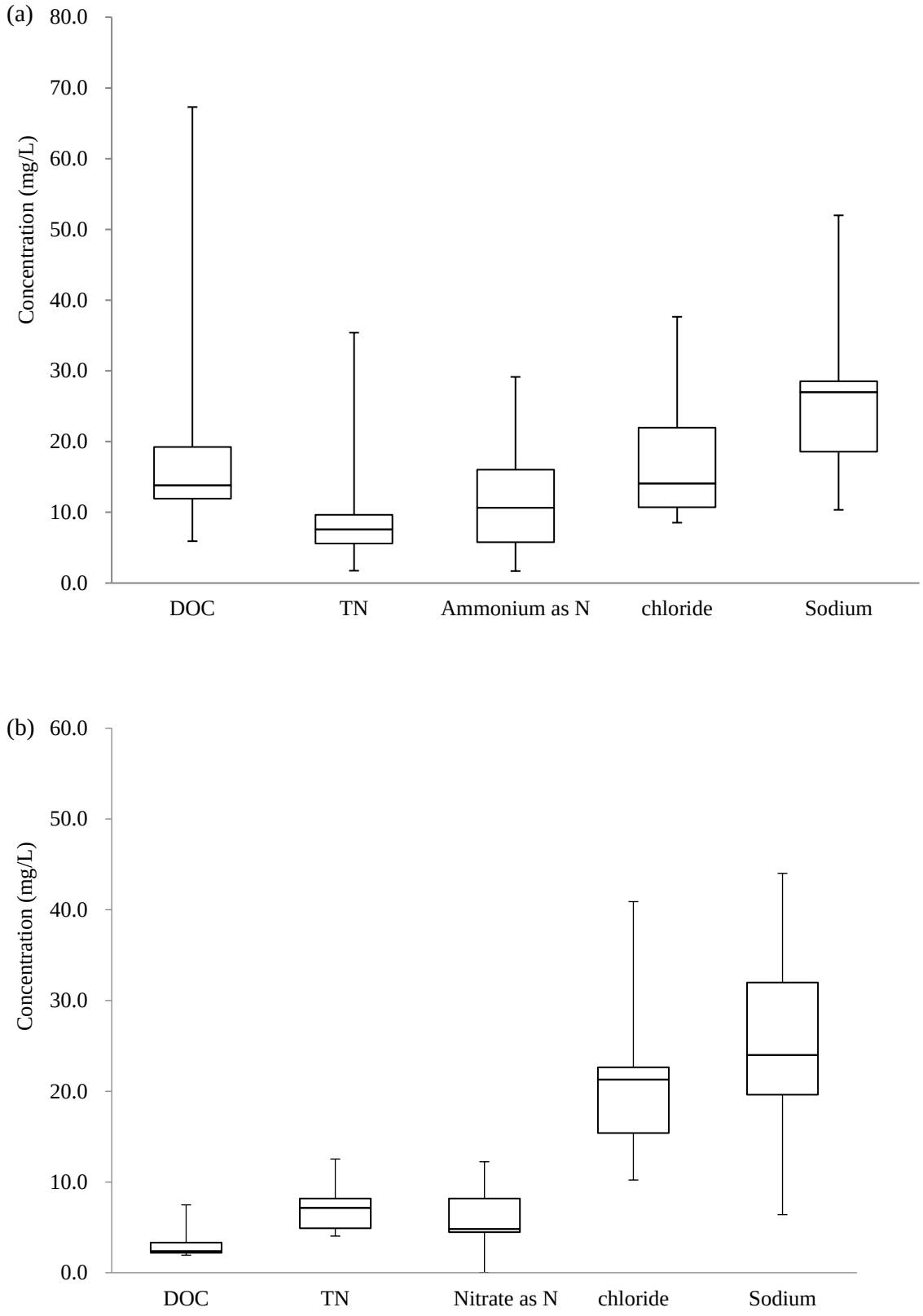


Figure 5.22 Water characteristic of (a) influent and (b) effluent samples

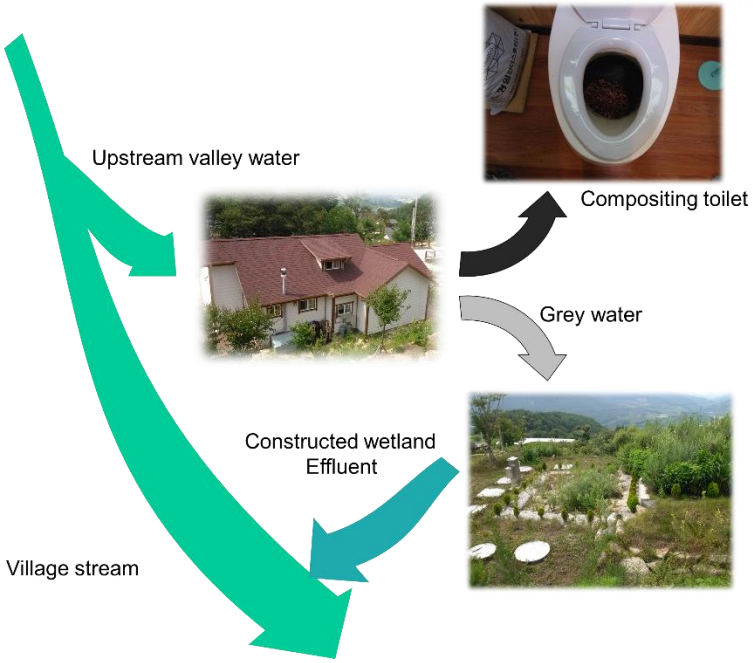


Figure 5.23 Water system of small village

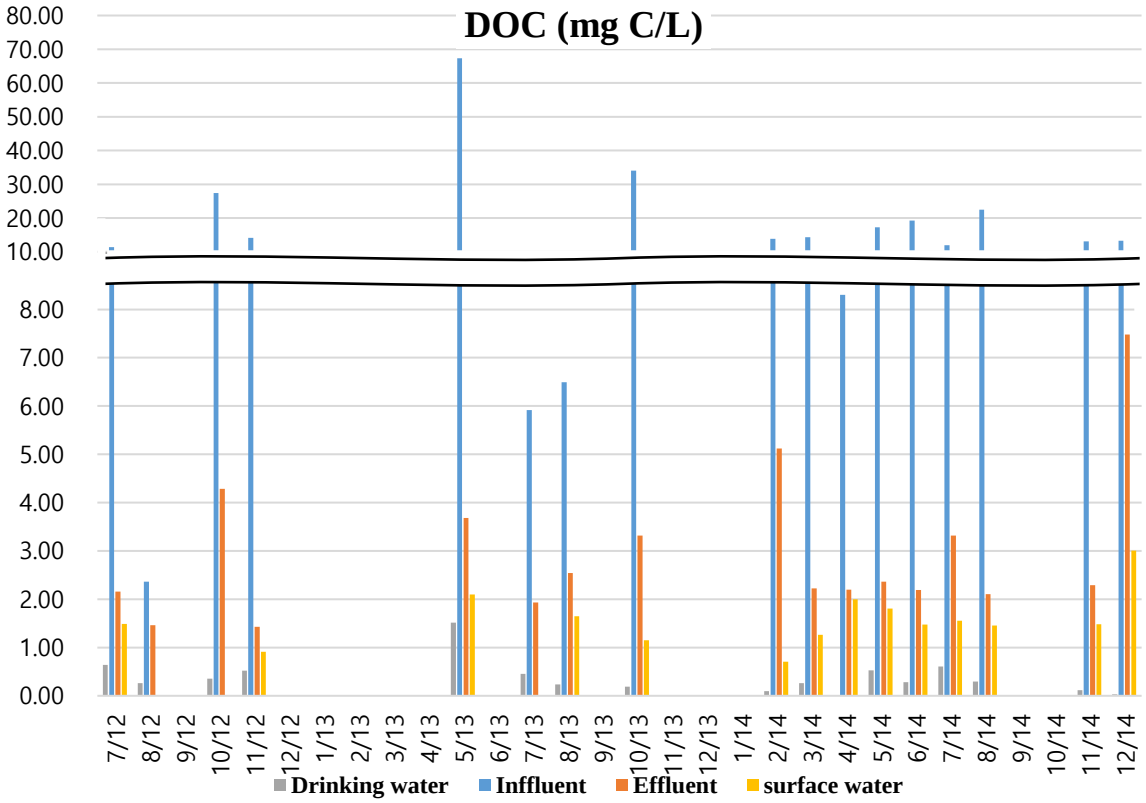


Figure 5.24 DOC concentration depending on sampling sites

2) Organic matter characterization according to molecular size

Concentrated samples (sampling date: 21 October 2013) were injected into the prep-HPLC for fractionation. The chromatogram of the samples is shown in **Figure 5.25**. The effluent sample was separated into two peaks (E1, E2) and the influent was separated into six peaks (I1, I2, I3, I4, I5, and I6). The separation principle of the Toyopearl GROM column is size exclusion; therefore, the molecular weight of each peak was different. The chromatogram indicates that peaks in similar time have similar molecular size. Therefore, peaks I2 and I3 have a molecular size similar to that of peaks E1 and E2, respectively. Compared with the effluent, some parts (I4, I5, and I6) of the organic matter in the influent were interpreted as removing by the constructed wetland. The SUVA values were calculated from the fractionated samples to characterize each peak (**Table 5.7**). The E1 and E2 peaks had molecular sizes similar to those of I2 and I3, but their SUVA values were higher than were those of I2 and I3. Because SUVA values can explain hydrophobicity, this result indicates that the organic matter in E1 and E2 could be organic matter changed into humic substances by humification. As regards I5 and I6, they also show high SUVA values, but these values could be overestimated because of the low DOC concentration.

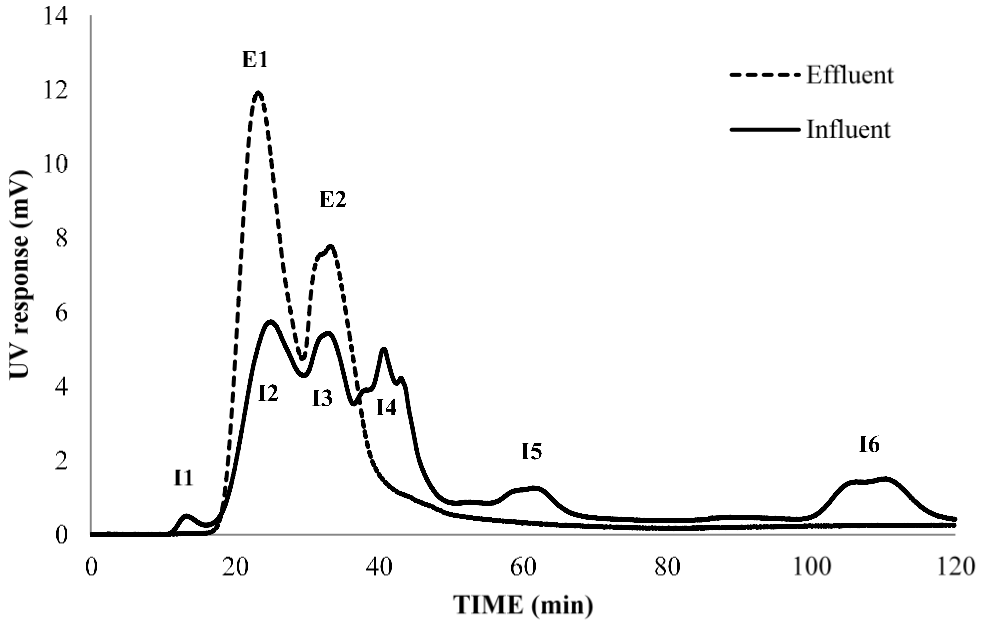


Figure 5.25 Prep-HPLC chromatogram from influent and effluent of constructed wetland

Table 5.7 SUVA values of fractionated samples

Sample		DOC (mgC/L)	UV (254nm)	SUVA
Effluent	E1	5.3	0.1310	2.5
	E2	2.1	0.0602	2.8
Influent	I1	4.0	0.0150	0.4
	I2	7.4	0.0729	1.0
	I3	8.7	0.0948	1.1
	I4	1.8	0.0458	2.6
	I5	0.5	0.0206	4.5
	I6	0.2	0.0172	7.1

5.4 Summary

The humification analysis by py-GC/MS indicates that the cow manure compost had the highest humification results by the highest lignin and PHA portions. However, the compost based on human feces could be utilized as an alternative fertilizer because its biomolecular structure was similar to that of the commercial organic fertilizer.

Compost contains high levels of nutrients, but its high salinity is a limiting factor. As this is caused by diet, it is not easy to reduce the sodium and chloride concentrations. However, they also have high solubility. Irrigation and rain can reduce the concentration of sodium and chloride in the soil. Stored urine was indicated as a good liquid fertilizer, as the high concentrations of nitrate, potassium, and phosphate can be sources of nutrients to plants. However, the ammonia generated by ureolysis is a negative factor as it leads to nitrogen loss. Furthermore, the unpleasant smell emanating from urine stored in the house is another limiting factor to its utilization. The improvement of the storage technology of compost and urine in urban areas is a primary requirement for their utilization.

The constructed wetland for greywater treatment showed a high level of contaminant removal efficiency. Separating the human excreta from the wastewater is an effective method to increase the wastewater treatment efficiency because it decreases the contaminant loading rate. Accordingly, if the human excreta can be separated, a constructed wetland could be an alternative wastewater treatment system in urban areas. The constructed wetland and composting toilet represent a meaningful attempt to improve the wastewater treatment aspect and urban ecological aspect of human society.

CHAPTER 6

Biographical research of the artists who made their artworks with excreta

6.1 Introduction

Biographical research was conducted relevant to the artists who had used excreta in their artwork in the attempt by the current study to change the negative perceptions of the waterless toilet. Fecal matter is associated with unpleasant sensations, such as stench, parasite, and infectious disease. The mental image of feces has no aesthetic aspect. In respect of environmental engineering, fecal matter is regarded as a significant water contaminant. However, excretion is an inevitable part of human life. The strong repulsion toward images of feces induces indifference about the study of fecal matter. Artists are regarded as people who consider fundamental concepts, such as the meaning of life. The artworks deriving from such consideration could influential the attitudes of "ordinary" people. The study methodology and theoretical background of the arts could be helpful in changing the negative perceptions of feces by enquiring what the meaning of feces was. Accordingly, the purpose of this chapter is to determine the opinion of artists about feces and, in so doing, give people a chance to reconsider the meaning of feces. The results can be employed in the research on the individual in-depth interviews, intended to change the negative perceptions on feces with scientific data. In this chapter, two artists are introduced, namely, Piero Manzoni (**Figure 6.1a**) and Kwon Chong-saeng (**Figure 6.2b**). They considered the meaning of feces in human society. In investigating their artworks, the meaning of feces could be redefined.

Figure 6.1 (a) Piero Manzoni, (b) Kwon Chong-saeng

6.2 Artists profiles and Characteristics of artworks

This study was followed these research questions.

1) The research questions

- Where did they get inspiration with their ordinary artworks?

- What is the goal as an artist?

- Why did the artists use the excreta in their artworks?

6.2.1. Piero Manzoni (1933~1963)

1) Artist profile

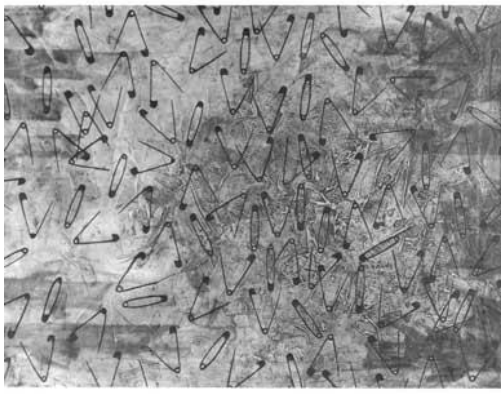
Piero Manzoni was an Italian avant-garde artist, who was born in Soncino, Italy, in 1933, and started painting at seventeen. After commencing legal studies at the Accademia di Brera, he changed his majors to art and philosophy. In 1953, he took private drawing classes. As a young man, he tried to paint traditional landscapes (*Santa Margherita Ligure* [1953] and *Albisola Marina* [1953]). In 1955, he started using alternative materials in his artwork, such as tar, scissors, pincers, or buttons. He was impressed by the work of Alberto Burri, Lucio Fontana, and Yves Klein. In 1957, he created *Achromes*, a completely white canvas covered with glue and liquid kaolin. He tried to create colorless artwork because he thought that paint should be expressed only by paint, without the disturbance of color. He also tried to realize universal values regardless of the materials used. He later joined the conceptual art movement, i.e., concepts or ideas take precedence over traditional aesthetics and material concerns.

2) Where did he get inspiration to create his ordinary artworks?

His art was created between 1956 and 1963, and despite the short time span, he left a strong impression on art history. In 1956, he displayed an artwork of everyday objects such as keys, scissors, and safety pins (**Figure 6.2(a)**). According to his first manifesto, *For the discovery of a zone of images* [76], he believed that everything was humanly communicable and that artwork originated in an unconscious impulse that springs from the collective substrata of universal values common to all men. In addition, he mentioned that pictures could not be considered as spaces onto which to project our mental scenography. Piero Manzoni thought everyday objects could be artworks, which could inspire people. In 1957, he exhibited *Achromes* **(Figure 6.2 (b)**), one of his

greatest artworks. These artworks were made in series from 1957 to 1962. The term "achrome" means the absence of color, or "uncolor." He wanted to express an empty space without any colors or lines because he thought these signs could imply unexpected meaning to the viewers. He aimed to create an artwork without containing the immediate materials because he was interested in anti-expression in the materiality of the art object. The *Achromes*, which was created in 1961, was made with colorless materials such as cotton, felt, fiberglass, or bread rolls **(Figure 6.2 (c)**). Piero Manzoni wanted to show his capacity for visual self-determination. In 1961, he displayed a radical artwork titled *Artist's shit* (**Figure 6.2 (d)**). On the label, the sentence was printed, "Artist's Shit, contents: 30 grams net, freshly preserved, produced and tinned, in May 1961." His reputation increased because of this artwork. However, no one knows what the cans really contain. This artwork aroused viewers' curiosity and individual various imaginations. One of Manzoni's friends insisted that the cans contained plaster, whereas his girlfriend said that it was feces. He intended people to become inspired by the artwork showing the artist's own body. He thought real artwork was the artist's vestiges becoming precious relics.

(a)



(b)

(c)

(d)

Figure 6.2 Artworks of Piero Manzoni (a) Pins 1597, Oil, tar on canvas (98 x 130 cm) captured from Piero Manoni Archive [82] (b) Achrome 1958 captured from TATE [83] (c) Achrome 1961-1962, Bread rolls, kaolin on canvas (31 x 31 cm) captured from Piero Manzoni Archive [82] (d) Merda d'artista (Artisit's shit). 1961

3) What is the goal as an artist?

Manzoni's goal as an artist was explained by his manifesto. As already mentioned, he published the manifesto in 1956, titled *For the discovery of a zone of images*, He wrote, "*...artworks has its origin in an unconscious impulse from a collective substrate of universal values common for all men, from which all men draw their gestures, and from which the artist derives the "archai" of organic existence*." *Archi* means that primary senses, i.e., "beginning," "origin" or "source of action." In his opinion, artworks start from everywhere, with the origin being a type of invisible emotion. He avoided materialized results in his artwork, and tried to incapacitate the limitation caused by pictures. *Achrome* is Manzoni's representative artwork about this idea. The attempt to reveal natural materials in the artworks suggests the pure meaning of the materials, without disturbance from various artificial

techniques. As he used alternative materials, such as cotton padding, acrylic resin, and kaolin, he created special artwork with the capacity for visual self-determination. In 1957, he declared that, "*We want to organize disintegration. In a disintegrated world, we want to be able to discover and reveal to ourselves the inner structures*" [77]. As an avant-garde artist, he avoided normal artists' materials and used organic materials, such as rabbit fur or human excreta, instead in order to realize the universal values, as mentioned in his first manifesto. His continuous study on approaching the universal values is expressed in artworks such as *Artist's Shit* (1961) and *Artist's Breath* (1960). He attempted to create interaction between the artist and viewers by his artworks. His effort to connect the human mind and universal values is explained in his statement, "*Art is not a matter of hedonism, but of bringing to light preconscious, universal myths and reducing them to an image. Art, therefore, is not a descriptive phenomenon, but a founding scientific praxis*" [78].

4) Why did he use the excreta in his artwork?

After displaying *Artist's Shit*, he evaluated the tins according to their equivalent weight in gold. His intention with the artwork is explained in a letter to the artist Ben Vaulter, "*I should like all artists to sell their fingerprints, or else stage competitions to see who can draw the longest line or sell their shit in tins. The fingerprint is the only sign of the personality that can be accepted: if collectors want something intimate, really personal to the artist, there's the artist's own shit, that is really his"* [79] Because feces were in the human body before excretion, they are part of the body. His insistence is an extreme example of the notion that anything from an artist is art. Byun Jong-phil wrote in his column that the artwork was created to suggest the message that everything had meaning, and there was nothing meaningless [80]. Gerald Silk mentioned [81] that Manzoni did not intend to simply shock viewers. He said that it was a result from the strain of avant-garde history, because Manzoni wanted to innovate art. In addition, Gerald Silk suggested that Manzoni became the artist with the Midas touch, converting feces into gold, as he connected feces with gold. It was a very powerful message to the art community. With this attempt, Manzoni showed the relationship between art and the commodity. His artwork was sold for approximately 10 500 dollars by Sotheby's in 2000. Another interpretation of *Artist's Shit* is that the artwork relates to individuality and commonness, meaning that fecal matter is produced by everyone and the make-up of one's feces is distinctly his or her own. In his artworks, Manzoni tried to describe the connection between individuality and commonness and the relation between being human and universal values.

6.2.2. Kwon Chong-saeng (1937~2007)

1) Artist profile

Kwon Chong-saeng was born in Japan but returned to Korea after the liberation of Korea. When he was five years old, his sister told him about God, after which he became a believer. From that time, his faith was the driving force in his life that enabled him to overcome hardships. As his family was poor, he had to start working as a child. Despite the poverty, he excelled in elementary school, graduating at the top of his class. He had a passion for learning but he was not allowed to start middle school, as his family expected him to work to support the family. At 18 years of age, he was working in Busan as a clerk. He was fond of reading and at that time was reading works such as *Crime and Punishment*, *The Sorrows of Young Werther*, and *A Sad story of Danjong*. At the age of 32, he was awarded a prize by the first Christian Children's Literature Contest for his children's story *Doggy Poo*. Subsequently, he published many works of literature, such as children's poems, children's stories, and Christian essays. Although he had suffered from tuberculosis from the age of 20, he was a prolific author, writing 140 children's stories, 100 children's poems, and 150 essays. Although he received author's royalties for his many popular books, he preferred living frugally. Kwon Chong-saeng died in 2007. A foundation to help children was established, as was stipulated in his will.

2) Where did he get inspiration to create his artworks?

The motivation for creating his works of literature mainly stemmed from his tough life. His themes relate to his chronic disease, poverty, the pain from the historic situation of Korea, and the Christian faith. At the time he was born (1937) in Japan, Korea was a colony of Japan and his family was subjected to discrimination. In 1948, Japan relinquished its control of Korea, but the hardship continued because of the Korean War (25 June 1950–27 July 1953). He suffered from tuberculosis and lived in abject poverty until his death in 2007. However, his religious beliefs sustained him. His experience with anger and sorrow was his inspiration for writing. Because of his anguished life, he could formulate a concept of the ideal life, which made his literary work more truthful. In his stories *Sister Mong-sil* and *Mommy and Cotton Jacket*, he depicted strong maternal love through the heroines, who experienced the pain of war and colonization. Even though the character Mong-sil was not a mother, her devotion to her family fully demonstrated the concept of maternal love. In his work, Doggy Poo, he explained the Christian belief by describing the transition from a petty to a meaningful thing.

2) What is the goal as an artist?

Trampled and abandoned things appear frequently in his work, and the main characters are shown as growing up to be strong despite difficult circumstances. He believed that God was always with us in the shape of a poor or weak person, and he tried to explain God's will by poor and weak people finding their life purpose by overcoming hardship. He believed that true happiness existed in poverty. He wanted to suggest a moral approach for a happy life by attempting to show the small joys that occur in the life of poor and weak people. His stories describing hardship appealed to and resonated with many readers. The author revered his mother, who had dedicated her life to taking care of her children. According to Lee Keysam [82], who is a high school teacher and a writer of children's stories, Kwon Chong-saeng described his mother in this way, "She always endured toothache" and "She ate ugly oriental melon, but she gave her son the delicious one." He was influenced by the self-sacrifice of his mother and expressed his opinions on a valuable life in his literary work. He hoped to inspire people to love each other selflessly and compassionately through his stories.

4) Why did he use the excreta in his artwork?

This story starts with a picture of a puppy pooping, leaving behind the small and delicate turd of doggy poo. Doggy Poo cannot move anywhere, but various living and inanimate natural objects visit him, advising him about the meaning of life. The first visitor is a lump of soil, who ridicules Doggy Poo because he thinks the poo is simply the dirtiest thing. Later, he regrets his behavior and consoles Doggy Poo. Then he tells his own life story, with self-reflection. Finally, he says that God never makes useless things. This advice prompts Doggy Poo to consider the purpose of his own life. The second visitors are a hen with chickens. The hen tries to eat Doggy Poo, who is scared, but decides to be a meal for the chickens. However, the hen leaves Doggy Poo in peace, as she thinks that he might not have enough nutrients for her babies (chicks). This makes Doggy Poo doubt the value of his existence. At night, Doggy Poo yearns for the bright stars and laments his misfortune. The last visitor is a dandelion sprout, who asks Doggy Poo to become a fertilizer. Finally, he discovers his life purpose and becomes absorbed in the flower that looks like a bright star. In this story, Kwon Chong-saeng considers life in terms of the Christian faith. The statement that God never makes useless things tries to explain the meaning of life with a trivial object such as doggy poo. To people, doggy poo is a dirty and useless thing, but the doggy poo becomes a flower through self-sacrifice. By showing that dirty doggy poo can change into a beautiful flower, the writer expresses the provision of nature. In another work, *Bapdegi Jukdegi*, he also used excreta as a story subject. The main characters, Bapdegi and Jukdegi appear in a dung tub and make dung powder to spread into the sky. The dung powder is magic powder that is able to remove weapons and wire fences. Furthermore, it can change people's minds to be willing to make a union. In this

way, the excreta are used as a medium to provide meaning to life. Kwon Chong-saeng wrote these stories to spread a message about peace and love by using excreta that is considered dirty.

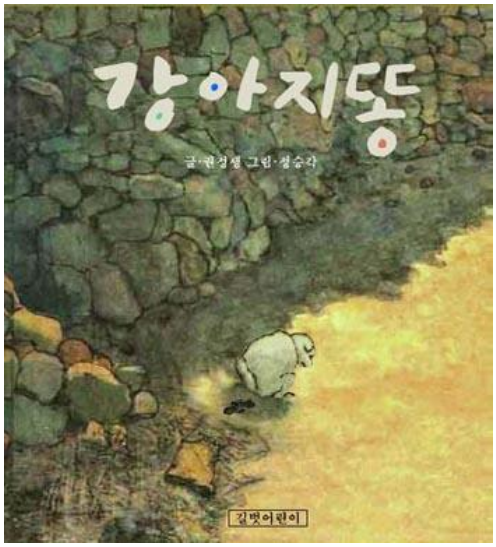


Figure 6.3 Kwon Chong-saeng. Doggy Poo. 1996

6.3 Data analysis

Manzoni used human feces and Kwon Chong-saeng used doggy poo to express their opinions. However, Manzoni's artwork was shocking to people, as it was simply a can containing his own feces. On the other hand, Kwon Chong-saeng described the doggy poo as a cute and lovely child. This is because their purposes differed. Manzoni wanted to show what the artistic essence was. He continuously considered: 1) What should I make as an artist? 2) What is real artwork that includes the essence of the artist? The answer to these questions created the *Artist's Shit.* Kwon Chong-saeng tried to show the value of existence by writing a story with dirty and trivial doggy poo as the subject. He wanted to show that there were no meaningless things in our world. The motivation for the artworks reflects the background of the lives of the artists. Manzoni and Kwon Chong-saeng lived during the post-war period. Manzoni tried to escape the existing culture and standards and became one of the avant-garde artists. Kwon Chong-saeng tried to find the happiness even in a painful situation. The common aspect between them is the attempt to reduce the hardship in society by creating an alternative meaning. They considered the meaning of matter in the attempt to achieve this goal. This attempt can relate to the present attempt to understand feces. Many people are threatened by environmental pollutants. In the flush toilet system, feces are treated as harmful and valueless objects. However, compared with chemical compounds, feces are not considered critical contaminants, probably because people do not have any interest in them. There is indifference about feces, they have been forgotten and have lost their meaning.

However, two artists insisted that feces were critical objects that related to the essence of humanity. In addition, according to these artists, feces could be considered a part of the human body and therefore essential products. Art plays the role of querying what the meaning of life or matter is. As discussed in this chapter, the artists asked what feces were in our society. Their questions and answers provide valuable information for the artistic approach in the convergence of science and arts methodologies.

6.4 Summary

The information obtained by a comparison between the two artists, is presented in **Table 6.1**. The biographical research methodology was employed to investigate the two artists, namely, Piero Manzoni and Kwon Chong-saeng for the artistic approach. This chapter focused on finding the meaning of feces in the artworks that employed excreta as subjects. Manzoni was an avant-garde artist, whose style was influenced by Alberto Burri, Lucio Fontana, and Yves Klein. art emphasized emotions, undisturbed by the shapes or color of the artworks. He was interested in depicting the essence of the artist. His artwork *Artist's Shit* was shocking, but he wanted to explain that feces were a part of the human body. Therefore, to Manzoni, feces represented the real artwork of the artist. Kwon Chong-saeng suffered many hardships in his life, including illness and poverty. However, he endured such hardship and wrote beautiful stories about the Christian faith. In his children's story about Doggy Poo, he emphasized that there were no meaningless things in our world. He tried to show that everything had a purpose.

Table 6.1 Summarized data from the artists

Artist's name	Piero Manzoni	Kwon Chong-saeng
Occupation	Artist	Writer
Feces related artwork	Artist's shit	Doggy Poo
Purpose	What is essence	A meaning of existence
Reason	The real artwork should be from the artist's body	There are no meaningless things
Spectators reaction	Shocking and unusual artwork	Cute and interesting story for children
Related points of the artworks to this dissertation	Piero Manzoni tried to show what reality was. Even though his art was shocking to people, he believed that feces were part of the human body. Kwon Chong-saeng's story is based on Christian belief. God loves humans and nature. The artists' opinion is that feces are not simply waste. Since the study objective in this dissertation is to reduce the negative perceptions on feces, the purposes did not match perfectly. However, the attempts of the artists appear to relate to the way in which human beings consider feces. This is the meaningful results from the research described in this chapter.	

CHAPTER 7

Individual in-depth interview for applying the methodology of the convergence of science and arts

7.1 Introduction

Feces and urine are important to human beings, as they prompt people to recognize that eating and excretion are normal human behavior and that people are a part of nature and can donate their excreta to provide nutrients to nature. Every human being is included in this behavior and meaning, regardless of his or her social status. However, people tend to disregard feces even though they cannot escape from them. They tend to idealize themselves, as feces and urine are categorized as taboos. The flush toilet system is a representative utility that reflects the negative perception. People use the flush toilet mindlessly, simply relieved to remove the dirty objects from their surroundings. However, feces and urine still exist near us, collected in a massive wastewater treatment plant. Consequently, the dirty things are not removed, but simply moved to another location.

In his book, *Wasted Lives: Modernity and its Outcasts*, Zygmunt Bauman mentioned that globalization generated waste. He thought that modernization could be categorized into developed and undeveloped with an industrialization aspect [83].]. In his opinion, the flush toilet is considered a modern utility, whereas the other types of toilets are disdained as undeveloped things. People have improved their lives by modern conveniences such as the flush toilet; however, the negative perceptions on excreta lead to devaluating feces and urine. Moreover, this has a negative effect on the carbon cycle in the environment.

This study employed a methodology related to the convergence of science and the arts in an attempt to change the negative perceptions on excreta. Rationality and intuition are major human mental abilities, with science focusing on rationality and the arts on intuition. In the study, two converged disciplines were applied to change the perceptions on feces. The general perceptions on feces were studied by providing scientific and artistic data to interviewees during the individual in-depth interviews. As this study about categorizing between changeable and unchangeable parts, it will be able to suggest the informative results for solving the environmental problems which were occurred by the flush toilet.

7.2 Study methodology

The artistic perceptions (Chapter 6) and the scientific results on feces (Chapter 5) were provided to the interviewees. Five interviews, lasting 20 minutes each, were conducted to monitor the change in perceptions. During the final interview, the changeable or unchangeable aspects were discussed with the interviewees.

1) Selecting the interviewees

To investigate the possibility about changing perceptions on feces, there were two selection criteria for finding interviewees. The first criteria is the project experience related feces. Because the interview will discuss about feces, it required that a person doesn't feel a strong repulsion toward feces. Second one is the understanding of scientific knowledge. The scientific data will be provided for convergence between science and arts, so I found a person educated in science or engineering field to conduct the interview smoothly. The originality of the interview is that I selected ordinary persons. They were not representative persons. This approach is to suggest an alternative viewpoint for research. As I concentrated to the person included in a group, I thought that the weak point of representativeness would be covered. Quantitative researches have used the statistical method, and then people believed that is the representative data. However the result also means that it is a tendency, so it does not perfectly match with every case. It is the limitation of representativeness. To compensate the lack of precision about data, it is necessary to study with a qualitative method. Therefore, the ordinary persons were interviewed, and their perceptions were deeply investigated in this dissertation.

The interview process was followed by the regulation of Institutional Review Board (IRB). Since this research focus on the changing perception of feces during the interview, the risk or disadvantages that can be affected on the interviewee is very few. In addition, the questions and suggested materials are not included in the critical personal information area.

2) Interview process

The interview process followed the regulations of the Institutional Review Board (IRB). However, this research focuses on changing the perceptions on feces during the interview; therefore, the risks or adverse effects to the interviewee were minimal. In addition, the questions and suggested materials were not included in the critical personal information area. This study aims to find the changeable perceptions of feces, and it is difficult to estimate the results with quantitative values. To compensate for this weakness, the mind map technique was used to compare the perceptions on feces before and after the interviews. During the interview, the scientific and artistic data on feces were provided to the interviewees. Using excreta as fertilization and the alternative wastewater treatment system without

human excreta were introduced to consider the physicochemical information on feces. In view of the arts methodology, the perceptions of the two artists on excreta were provided to prompt the interviewees to reconsider the meaning of feces. Then every sentence in the interview was written in here and keys words were categorized and analyzed after the interview.

2) Research questions

The research questions comprise five major topics, which include several interview processes, to obtain detail information from the respondents.

Table7.1 Major questions and implicit research processes

Interview topic	1. What is the general perception on feces?
Implicit research process	- Drawing a mind map - According to the results, specific reasons will be collected from the interviewees. - Categorization of perceptions, dividing into negative and positive
Interview topic	2. Meaning of feces
Implicit research process	- Introduction of artworks made with feces - Discussion about the artworks and the purpose of the artists - Asking about the meaning of existence and dirt
Interview topic	3. Scientific results about feces
Implicit research process	- Introduction about the composition of feces - Explanation of the source of the unpleasant odor - Scientific benefits relate to feces - Explanation of wastewater treatment system and flush toilet
Interview topic	4. Finding the changeable or unchangeable perceptions of feces
Implicit research process	- Redrawing a mind map - Categorization of perceptions, dividing into negative and positive

7.3 Contents of interview

7.3.1 Mind map results

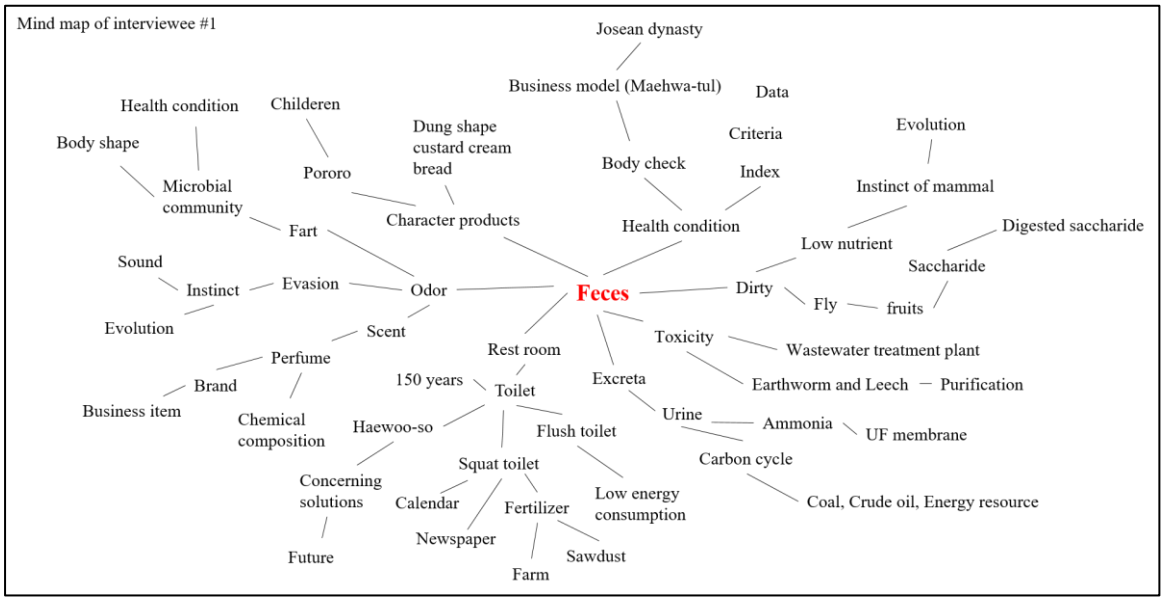


Figure 7.1 Mind map about feces of interviewee #1

Interviewee #1 showed a neutral attitude toward feces (**Figure 7.1**). He considered feces as dirty and disgusting, but also thought it was a nutrient resource and a business item. He suggested five major topics about feces, namely, 1) toilet, 2) excreta, 3) dirty thing, 4) odor, and 5) character product. Several concepts were associated with the word "toilet," such as flush toilet, fertilizer, and private place for considering troubles. He mentioned, "*Toilet was invented for removing feces, and removing feces can be a symbolical behavior for removing troubles.*" He also thought excreta were not simply dirty things, but provided vital information for health care, as the composition of feces relates to personal diet; therefore, analyzing feces could provide information on health. He pointed out that the odor was a representative unpleasant characteristic of the feces. His opinion is that the odor of the feces is a sign that can indicate danger, so changing or removing the odor can decrease the negative perceptions on feces in human beings. However, he also considered the positive aspect of feces as a fertilizer. Mineral nutrients and organic carbons are important factors to include in the ecosystem. He suggested a business idea related to organic fertilizer. As organic products that are not contaminated by chemical products are becoming popular, organic fertilizer from the feces of vegetarians or organic food consumers could be valuable products. Another example is a characteristic food, namely, custard cream bread that has a fecal shape. He emphasized that everyone knows feces is dirty and dangerous, but it still has helpful aspects to our society. A change in the negative perceptions of feces will become possible when science and technology about feces is developed.

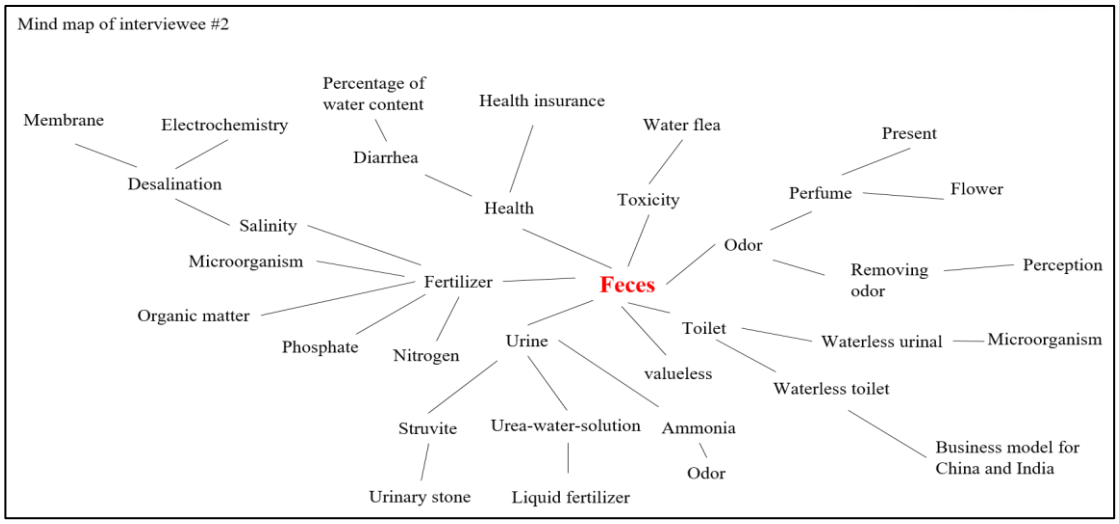


Figure 7.2 Mind map about feces of interviewee #2

Interviewee #2 had more positive perceptions than interviewee #1 had. His overall perception of feces was that "*it can be a good research topic which can provide environmental solutions to our society*." In his mind map results, 20 of the 35 words related to the scientific aspect (**Figure 7.2**). He presented five major topics, namely, 1) odor, 2) toilet, 3) urine, 4) fertilizer, and 5) health. The word "odor" was associated with "removing odor" because he thought odor was the strongest characteristic of feces. This opinion was similar to that of interviewee #1. However, he had a different opinion about how the odor should be treated. "*I think totally removing odor is not a good idea, because it means that we admit feces is dirty and unpleasant matter. To accept feces in our society as a resource, it is firstly needed to recognize that feces are a friendly matter although it has a bad smell. For example, durian is well known as a smell bad fruit, but people eat the fruit. Thus, it is more important to change the perception on feces than to remove bad smell*." This differs from the opinion of interviewee #1, who thought that odor was a key factor that generated the negative perception. Interviewee #2 mentioned a business model involving a waterless toilet. He said that water shortage was a serious problem in our world; therefore, the waterless toilet could be an effective business idea for the environment and the economy. He associated the word "urine" with struvite and the urea-water-solution. Struvite could be used as a fertilizer and the urea-water-solution could be used to reduce the nitrogen oxides emitted from diesel engines. In addition, he considered the composition of fertilizer made from feces. Microorganisms, phosphate, nitrogen, organic matters, and salinity were associated with the word "fertilizer." He associated diarrhea, toxicity of feces, and health insurance with the keyword "health." Most of his perceptions related to the science and engineering fields. He believed that science and technology could change the characteristics of feces; however, it was more important to change the perceptions of people. He emphasized, "*We firstly should try to recognize what feces are*."

7.3.2 Meaning of feces

After the first interview to draw a mind map, I spoke with the two interviewees separately and asked what the meaning of feces for human beings was. Interviewee #1 answered, "*Excreta is an obvious evidence about that human beings are a part of nature because excretion is a natural behavior as animals.*" When I asked, "Why do people avoid feces in their life, even though it has important meaning," he said, "*The first reason relates to genetic factors in human beings, and the second one is an education system in human society*." As he had mentioned before in the mind map results, he believed that genetic factors and evolution had a major influence on human behaviors, even in the perceptions on feces. According to this opinion, human beings have imprinted negative perceptions in their DNA, because feces are considered to have low nutrients, dangerous microorganisms, and a bad smell. In addition, he said, "*Education system reflects human society with the spirit of the age. Industrialization and civilization forced people to be excluded from nature. Industrialization wanted a person who works hard like a machine, and civilization separated human beings from the animal*." According to this opinion, people tend to regard excretion as a taboo because human beings do not want to be included with animal species. Therefore, people are indifferent to feces even though it has important meaning to humans. However, he insisted that the negative perceptions of feces could be changed by technical improvements. Perceptions are created by experience; therefore, if technology could ensure safety and convenience in treating feces it could generate positive experiences. Reconsidering the perceptions on feces would help to reduce the uncertainty by technology which was already mentioned by Zygmunt Bauman. This interviewee also mentioned, "*Persuasion with technology already started by climate change because scientists is speaking to people that we should consider we are included in nature*."

Interviewee #2 answered, "*Feces is a destiny which has to be accepted as a kind of animals*," when asked what the meaning of feces was. He explained that animals are freer than plants because they can move anywhere and select what they eat. In this situation, the excretion of animals is a restriction that cannot be avoided. After consuming food, animals have to release the residues from their bodies. Although it is troublesome, it cannot be avoided. Therefore, he thought that excretion was a kind of punishment, which is generated by free. The next question was, "Why do people avoid feces in their life?" He said that feces are the digested residues, which have low nutrients and therefor they are treated as useless and valueless, like trash. People easily throw away valueless things and never consider them again. He thought this was similar to the opinion on feces. No one considers feces after flushing the toilet. Because meanings such as useless and useful are allocated by people, he pointed out the anthropocentricism of such judgements. Furthermore, he recognized that human beings contaminated nature for their own convenience; however, he said that it was not sure whether this could be attributed to the human lifestyle. This is the reason that convenience is

associated to happiness for human beings. He said that it would be difficult to change the negative perceptions of feces, because the major reason why people avoid feces relates to education. Odor was also one of the major reasons for avoiding feces. He thought that the environment and social culture could have more influence on the negative perceptions. While someone is growing up, he/she is taught to avoid feces because it is dangerous and dirty; in this way, social concepts on feces can be passed down to the new generations. Therefore, he believes that changing the negative perceptions of feces would not be possible with only improved technology. For example, even if a fancy product were introduced, people would not use it if they did not realize that it was necessary. When the meaning of the artworks by Manzoni and Kwon Chong-saeng was suggested, the two interviewees had similar opinions. They agreed with the artists' opinions, namely, 1) feces could be representative of our existence and 2) feces were not useless objects. However, they said that the artists' methods of expression could be acceptable only to people in the past period. The interviewees mentioned, "*In case of Manzoni, he lived in the period that people desired the individual freedom and wanted to escape the war wounds. Because of the times, his artwork can come to the forefront. However, it would be difficult to get a lot of attention in the modern period when people enjoy freedom. Especially, as improving the entertainment technology, various visual contents were available, so feces in can would be not an attractive artwork*." On the other hand, the interviewees considered *Doggy Poo* an interesting story. However, they insisted that although the children's story contained a lesson, but it was too weak to suggest any positive perceptions of feces to people.

Table 7.2 Summary of the interview about meaning of feces

<table>
<tr><th>Questions</th><th colspan="2">Answers</th></tr>
<tr><td rowspan="2">What is the meaning of feces for human beings?</td><td colspan="2">Interviewee #1: "Excreta is an obvious evidence about that human beings are a part of nature because excretion is a natural behavior as animals”</td></tr>
<tr><td colspan="2">Interviewee #2: "Feces is a destiny which has to be accepted as a kind of animals"</td></tr>
<tr><td rowspan="2">Why do people avoid feces in their life, even though it has important meaning</td><td colspan="2">Interviewee #1: "The first reason relates to genetic factors in human beings, and the second one is an education system in human society"</td></tr>
<tr><td colspan="2">Interviewee #2: "Feces are the digested residues which has low nutrients"</td></tr>
<tr><td colspan="3">Providing the artists’ opinions about the meaning of feces</td></tr>
<tr><td colspan="2">Suggestion type</td><td>Information</td></tr>
<tr><td colspan="2">Oral introduction with supplementary data (printed picture)</td><td>- Piero Manzoni’s life
- Artist’s Shit
- Meaning of feces: Feces are a part of our body. They represent the essence of us
- Kwon Chong-saeng’s life
- Doggy Poo
- Meaning of feces: Feces are not waste</td></tr>
<tr><td colspan="3">Reactions from the information</td></tr>
<tr><td colspan="3">1) Feces can be representative of our existence
2) Feces are not useless objects
3) "In case of Manzoni, he lived in the period that people desired individual freedom and wanted to escape the war wounds. Because of the times, his artwork can come to the forefront. However, it would be difficult to get a lot of attention in the modern period when people enjoy freedom. Especially, as improving the entertainment technology, various visual contents were available, so feces in can would be not an attractive artwork."
4) "The children’s story can give a lesson, but it is too weak to suggest the positive perceptions on feces into the people."</td></tr>
</table>

7.3.3 Scientific data about feces

To investigate the knowledge about feces in the interviewees, several questions were prepared, namely, 1) Do you know what the chemical compositions are in feces? 2) What is the origin of malodor in feces? 3) Why do people think feces have toxicity? The conclusion was that the interviewees did not have specific information about the scientific characteristics of feces. They only had vague information in answer to the questions. Their answers were "*Feces have good nutrients for plant growth." "I don't know and have any interest the origin of malodor.*" "*The microorganisms have dangerous toxic materials.*" Their opinions were partly correct, but they appeared to ignore the beneficial aspects of feces. The scientific data of Chapter 5 were suggested to the interviewees, namely, 1) phosphate, potassium, and nitrate are the major ion species, 2) the origin of malodor is the volatile compounds, such as indole and skatole, 3) microorganisms include harmful and beneficial species for human health, such as *Bacteroides* and *Bifidobacterium*. After presenting the scientific data of the feces, the interviewees voiced their opinions. Interviewee #1 said, "*I think feces is dangerous because it can contain contagious bacteria such as cholera and dysentery. The risk of pathogenic bacterium will increase if we don't know who made the feces. Thus the public toilets without flushing system can be a very dangerous place.*" However, he suggested a positive opinion, i.e., that the installation of a waterless toilet at home was possible because it could reduce the uncertainty of the feces source. In addition, he said that if technology could remove the malodor, contagious bacteria, and unpleasant touch of feces, it would change the negative perceptions of feces dramatically. Interviewee #2 said, "*The correct and detailed information of feces is important, but it cannot effect on the change of the negative perceptions on feces. I think people will be changed when they recognized convenience or economic benefits.*" His opinion focused on the human preference for a convenient life. Nobody feels uncomfortable to use a flush toilet because of the familiarity and safety; therefore, people are not concerned with changing their lifestyle, even if they could benefit from the waterless toilet system. However, both interviewees were interested when I explained the characteristics of feces in terms of chemical compositions, source of malodor, and microbial community. However, they were unsure of the ability of technology to effect changes in human perceptions. They thought that people were only interested in what they wanted even though high-technology products were available. For example, people use smart phones, but the usefulness of the device depends on the users. Some people use it only for making phone calls, but other people use the various applications of the phone. Therefore, the two interviewees said, "*How to attract people's interest about feces is important, not only how to improve technologies about feces.*"

Table 7.3 Summary of the interview about scientific knowledge about feces

<table>
<tr><th>Questions</th><th colspan="2">Answers</th></tr>
<tr><td>Do you know what chemical compositions are in feces?</td><td colspan="2" rowspan="3">The interviewees did not have specific information about the scientific characteristics of feces
1) Feces have good nutrients for plant growth
2) I don’t know and have no interest the origin of malodor
3) The microorganisms have dangerous toxic materials</td></tr>
<tr><td>What is the origin of malodor in feces?</td></tr>
<tr><td>Why do people think feces have toxicity?</td></tr>
<tr><td colspan="3">Providing the artists’ opinions about the meaning of feces</td></tr>
<tr><td>Suggestion type</td><td colspan="2">Information</td></tr>
<tr><td>Oral introduction with supplementary data (printed graphs and tables)</td><td colspan="2">1) Phosphate, potassium, and nitrate are the major ion species
2) The origin of malodor is the volatile compounds, such as indole and skatole
3) Microorganisms include harmful and beneficial species for human health, like Bacteroides and Bifidobacterium</td></tr>
<tr><td colspan="3">Reactions to the information</td></tr>
<tr><td colspan="3">1) "I think feces are dangerous because it can contain contagious bacteria such as cholera and dysentery. The risk of pathogenic bacterium will increase if we don’t know who made the feces. Thus the public toilets without flushing system can be a very dangerous place"
2) "The correct and detailed information of feces is important, but it cannot effect on the change of the negative perceptions on feces. I think people will be changed when they recognized convenience or economic benefits"
3) "How to attract people’s interest about feces is important, not only how to improve technologies about feces"</td></tr>
</table>

7.3.4 Redrawing mind map

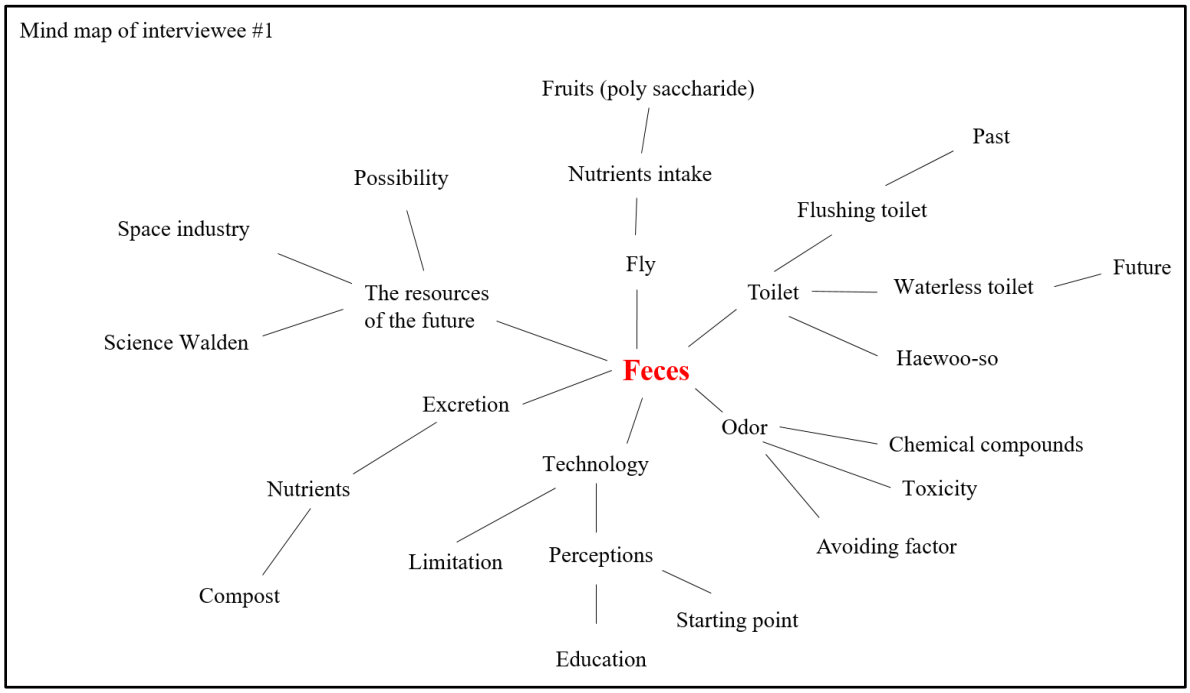


Figure 7.3 Redrawing Mind map about feces of interviewee #1 after the interview

As was mentioned in Chapter 4 (Methodology), the convergence point of science and arts was suggested as being located in the human mind. The two interviewees received the two types of information through individual in-depth interviews, namely, the scientific results of feces analyses and the artistic information on the feces. In this paragraph, the changing perceptions of feces are estimated by comparing the mind maps before and after the information was presented. The difference between the mind maps is regarded as indirect evidence that negative perceptions can be changed by the convergence of science and arts methodologies.

The second mind map of Interviewee #1 (**Figure 7.3**) was simpler than the initial one. When asked why the number of topics had been reduced, he answered, "*I felt that what I should focus on to understand feces. In the initial mind map, I draw a lot of image about feces. However, in this time, I considered only what should be thought to change the perceptions on feces, so I wrote down about technology and its possibility*." He also said that the flushing toilet system would be considered old technology and the waterless toilet would be the future toilet. He understood the limitation of the flushing toilet, i.e., the current water shortage problems could not be solved while the flushing toilet system was being used. In addition, he said what was required was not only improved technology but also an education system to change the negative perceptions on feces. As the existing perceptions stem from various personal experiences, the education system, which influences opinions from childhood, could be an effective means to change opinions on feces. Finally, he mentioned, "*People cannot live without feces because we produce them every day.*

However, we always try to remove them, but now we should consider they are not only waste. We should think the usefulness of feces as resources of the future to help us and solve the various environmental problems."

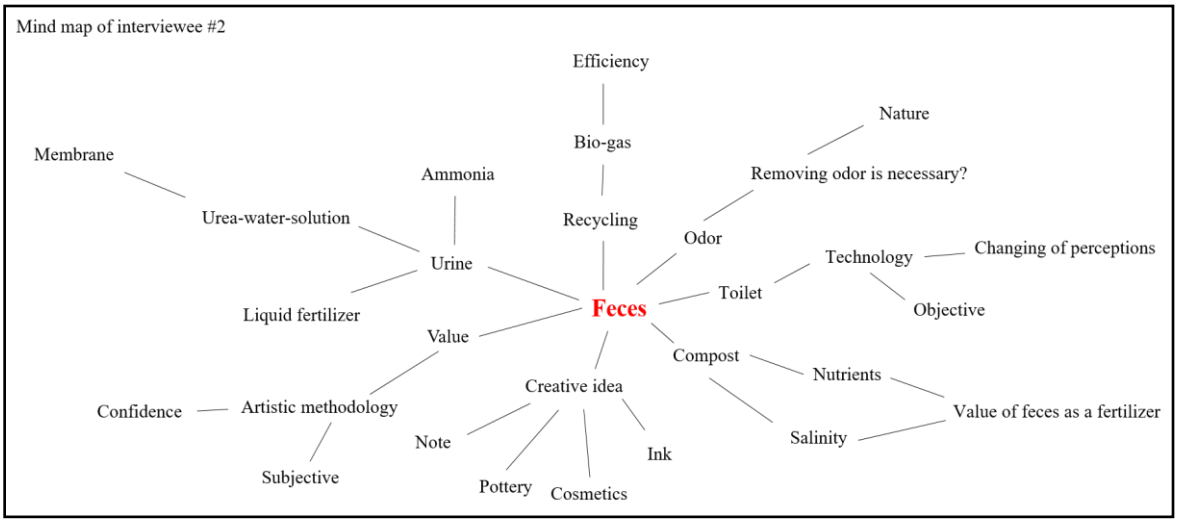


Figure 7.4 Redrawing Mind map about feces of interviewee #2 after the interview

The mind map of interviewee #2 was similar to that of interviewee #1 because he used words in his mind map that included scientific terms (**Figure 7.4**). However, he emphasized that the scientific approach was based on objectivity and the artistic approach on subjectivity; therefore, the proper strategy considering both aspects is necessary to change the negative perceptions on feces. He also said the experimental results with numbers could improve the objectivity and confidence, and philosophy could increase the subjectivity. He suggested an interesting example, namely, "*If a person, who is famous, sell a product originated feces with a high price, people recognize that the product price is high like a Manzoni's case. Thus, sometimes subjectivity has stronger effects on human perceptions than objectivity.*" He did not have a specific opinion on whether objectivity or subjectivity was a more important factor to change the negative perceptions. The interesting point is that he seemed to have more interest in feces than before the interview. He said, "*I felt that some of my perceptions on feces were identified by the interview. When I draw the mind map in first time, I just wrote the perceptions on feces unconsciously. However, after the interview, I can draw a detailed mind map with suggested information which help to expand my perceptions on feces.*"

7.4 Finding

7.4.1 Influence of interview with artistic information

The two interviewees had strong opinions on feces. They thought that feces were dirty, unsanitary, dangerous, harmful, and disgusting. When they listened to the explanation of the artworks, they were not interested in the artworks. The interviewees insisted that the Manzoni instance could only affect people in the particular historical circumstances. During the post-war period, people desired freedom because they wanted to escape from the pain of the war. It is interesting that the responses from both interviewees were similar. As regards the Kwon Chong-saeng story, they appeared to accept the writer's opinion because the story is based on the Christian faith, the principles of which are familiar to people whether they are Christians or not.

The different response to the two artworks probably stems from the media the artists used in their artwork. Manzoni used "real" feces, but Kwon Chong-saeng simply described it as having a cute and lovely character. Consequently, the interviewees had negative perceptions on feces when they were showed the Manzoni artwork, as it recalled the negative images directly. However, *Doggy Poo* did not show the real matter. In the story, the unpleasant images existed only as a meaning or a symbol and not as visual images; therefore, the readers could focus on the story without having negative perceptions. The finding was therefore that the direct introduction of feces increased the displeasure, whereas indirect introduction, as in the story, could decrease the negative perceptions on feces, probably because there were no images of dirty, disgusting, and malodorous feces. The two interviewees thought that the artistic approach could inspire people to reconsider the meaning of feces, but it had a limitation, i.e., that the artistic approach normally dealt with ideal situations.

The most interesting finding from the interview with the artistic information was the amount of knowledge of the interviewees about feces. The artists suggested questions about the real meaning of matters and they tried to concentrate their thinking in the artworks with very deep knowledge. This is the reason for artists often creating profound art that most people fail to understand. However, if a person viewed the artist's opinion with empathy, the artwork could influence his/her opinion about the meaning of life or matters. This could probably be ascribed to the characteristic of the arts that form a connection to people by intuition. In this study, the character of arts was revealed during the individual in-depth interviews. The interviewees were opposed to or accepted the artists' opinions. This was probably because the artists asked what the meaning of feces was to us. People are obviously quite familiar with feces, as they see and smell them every day. People cannot escape from feces and everyone has perceptions that originate from their individual experiences. Since these experiences form their perceptions, people obtain the

images naturally and form strong opinions about feces. Consequently, such opinions caused resistance to the artists' opinions. As the interviewees had thought already what feces were, they found the questions of the artists uninteresting. Perhaps, in their minds, they could say something like, "*I already know what you (artist) want to say, but the more important thing is different to me.*" The supporting existence for this opinion is presented in the next section (7.3.2 Influence of interview with scientific information). In short, the study found that the interviewees were interested in the scientific results because the information presented during the interview was something they had not considered before. The finding was that people already had their own opinions on feces and it was difficult to persuade them to change their perceptions with only the artistic approach.

7.4.2 Influence of interview with scientific information

The scientific information on feces was not familiar to the interviewees; moreover there is little academic knowledge on this subject. It realized also this situation when I was searching the information using the internet because there are only few academic knowledge. Therefore, I wanted to find the reason why few academic knowledge exist in our society during the interview. The two interviewees had only vague information about the scientific data on feces, which probably had been obtained from their parents, teachers, or the neighborhood. Sometimes they had their own negative experiences, but such cases were rare. To investigate this situation, I associated the lack of scientific information with the indifference to feces. As was reported on the response of the interviewees to the meaning of feces, the interviewees had abundant information on feces. However, most of this was negative. The negative perceptions induced the interviewees to consider feces as waste even though this originated from their own bodies. I wanted to describe the origin of the knowledge when we recognize a matter. Knowledge is formed by direct or indirect experiences. However, what if the source of the experience is incorrect information. This does not imply that the negative perceptions on feces are wrong, as these perceptions have been verified by human history. I just wanted to focus on the missing point when we image feces in our minds. The scientific results are considered truths because science has been developed to find truths. From the results of the interview, I thought that the lack of scientific information on feces could be one of the factors that had formed the negative perceptions. This was because the interviewees had various opinions but inadequate scientific information. Therefore, the negative perceptions on feces were probably based on the images, which had been obtained from emotional factors, and were not the true values. If perceptions could be based on scientific data, many existing negative perceptions could be changed.

7.4.3 Changing or unchanging perceptions on feces

The mind map technique was used to find ideas. In this study, I applied the technique to investigate the human perception on feces by comparing between the mind maps before and after the interviews. There were two findings, namely, 1) a decrease in the mind map branches, 2) a change in individual perceptions on feces. In the case of interviewee #1, the number of words decreased from 59 to 25 and scientific and technological words were used more in the mind map after the interview. There were three perceptions, namely, 1) the flush toilet is a technology of the past, 2) the waterless toilet is a promising system for the future, and 3) education is required for providing information on feces. The mind map of interviewee #2 after the interview also showed a decrease in the number of words (from 34 to 28) and more frequent use of technological terms. Two changed perceptions emerged, namely, 1) science induced the changing of perceptions by objectivity and arts induced it by subjectivity, and 2) applying feces to make compost is not special anymore; therefore, new technology for the application of feces is needed. Overall, it was verified that changing the negative perceptions on feces was possible, but this required new information that people had never considered before.

7.5 Summary

In this chapter, human perceptions were studied to find the changeable points when the interviewees had obtained scientific and artistic information about feces. This is because the human mind is the final convergence point in the convergence of science and arts methodologies. The interviewees showed they had strong negative perceptions on feces, and they voiced their opinions when the artistic information was provided. They did not think that the artworks were special, and the artistic approach for changing the perceptions had a limitation. On the other hand, they showed interest in the scientific information, because they had limited prior scientific knowledge about feces. They thought science and technology could change the negative perceptions dramatically if the problems of malodor and the sanitation of the waterless toilet could be solved. The changed perceptions were verified by comparing the mind maps before and after the interviews. Both interviewees showed a tendency to consider scientific words and to realize the importance of education on the essence of feces. The results in this chapter indicate that informative knowledge, which considers scientific and artistic aspects, is important to change the negative perceptions on feces.

CHAPTER 8

Summary and Conclusions

8.1 Summary

In this dissertation, human perceptions on feces were investigated in order to change the negative factors by the convergence of science and arts methodologies. This research aimed to provide significant information for changing human perceptions on feces. As the flush toilet system causes water shortages and aquatic environmental problems, the waterless toilet could be an effective alternative sanitation system. However, the flush toilet removes feces immediately from the house, whereas the waterless toilet has to store the feces until the feces are stabilized. This point is the critical disadvantage in utilizing the waterless toilet. To overcome this obstacle, it is necessary to change the negative perceptions on feces. The human mind is a critical factor in this issue and it is difficult to solve the problem with a scientific and technological strategy only. Therefore, the convergence of science and arts methodologies is applied in the current study, as both the human and the scientific factors are considered in studying the problem. The arts focus on intuition, which relates to the human mind, whereas science has practical logic based on human reason. The convergence of science and arts attempts to converge these components in the human mind by the qualitative research method.

For the artistic approach, two artists (Piero Manzoni and Kwon Chong-saeng) were investigated by using biographical research methodology. This chapter focused on finding the meaning of feces with artworks that relate to excreta. Manzoni tried to show the essence of an artist. His artwork *Artist's Shit* was controversial, but he wanted to explain that feces were part of the human body. In addition, he thought that feces represented human products. Therefore, to Manzoni, feces were the real artwork of the artists. Kwon Chong-saeng wrote a children's story about doggy poo, emphasizing that there were no meaningless objects in our world. The writer tried to show that everything had a life purpose, even doggy poo.

Data on compost, urine, and constructed wetlands were introduced as scientific results for the scientific approach. The humification analysis by py-GC/MS, indicated by the lignin and PHA portions, showed that the cow manure compost had the highest humification results. However, the compost based on human feces showed the possibility of being an alternative fertilizer because the biomolecular structure was similar to that of the commercial organic fertilizer. In view of ionic compositions, compost has high nutrients; however, the high salinity is a limiting factor. This relates to the diet; therefore, it is not easy to reduce the sodium and chloride concentrations. However, such concentrations also have high solubility. Irrigation and rain can reduce the concentrations in the soil. Stored urine was indicated a good liquid fertilizer. The high

concentrations of nitrate, potassium, and phosphate can be nutrient sources for plants. The ammonia, which is generated by ureolysis, is a negative factor because it induces loss of nitrogen. The unpleasant smell is another limitation when the urine is stored in a house. Therefore, to increase the utility of compost and urine in urban areas, adequate storage technology is the primary requirement.

The constructed wetland for greywater treatment showed high contaminant removal efficiency. Separating human excreta from the wastewater was an effective way to increase wastewater treatment efficiency, as it decreased the contaminant loading rate. Therefore, constructed wetlands could be alternative wastewater treatment systems in urban areas if the human excreta were separated. In relation to wastewater treatment and urban ecological aspects, constructed wetlands and composting toilets represent meaningful attempts to improve human society.

Finally, human perceptions were studied to determine the changeable points when the interviewees had obtained scientific and artistic information about feces, as the human mind is the final convergence point in the convergence of science and arts methodologies. At the beginning of the interview, the interviewees showed they had strong negative perceptions on feces, voicing their opinions when the artistic information was provided. They did not think that the artworks were special, and they thought the artistic approach for changing the perceptions had limitations. On the other hand, they showed interest in the scientific information because they had limited knowledge about feces. They thought science and technology could help to change the negative perceptions dramatically if scientific technologies could solve the malodor and sanitation problems of the waterless toilet. The changed perceptions were verified by comparing the mind maps drafted before and after the interviews. Both interviewees showed a tendency to consider scientific words and to realize the importance of education on the essence of feces. The results in this chapter indicate that informative knowledge, which considers both scientific and artistic aspects, is important to change the negative perceptions on feces.

8.2 Conclusions

The convergence of science and arts methodologies was designed for solving problems with the perceptions on human factors. In the approach to the problems with the human factors, this method aims to solve the problems with human perceptions, which are internal, and not only by matters that are external to the person. When this method was applied to a water contamination problem caused by the flush toilet system, it was found that perceptions on feces were the accumulated products of negative images. However, the essential information on feces was inadequate. In such a situation, the negative perceptions were reduced when the interviewees obtained the scientific and artistic information on the essence of feces. They also showed a tendency to change their perceptions by

their own reasoning, i.e., the information on feces decreased uncertain images, and changed human perceptions. The artistic approach played a role in asking the meaning of feces. Even though the interviewees did not agree with the selected artists' opinions, the different opinions offered a chance to reconsider the meaning of feces. The interviewees had only fragmentary experiences with feces, although confronted by feces every day; however, they could collect and combine the memories when they were refuting the opinions of the artists. Therefore, I do not think this implies that the artistic method to change the negative perception of feces failed. In fact, the approach was a great success, as it could trigger a change in the perception on feces from indifference to interest.

When we use the concept that perceptions are based on images, various study fields can apply this approach. In particular, it can be used to investigate the relation between scientific technology and human beings. People are living in the technological age, but few people consider the essence of the technologies, such as the operating principles or the source of the materials. On the other hand, they receive the images that come from the use of the technology. The accumulated images generate the perceptions and it could result in blind faith, similar to the negative perceptions on feces. Actually, people cannot recognize failed technologies that include harmful aspects. Even though the dangerous aspect could have been indicated, it could become apparent only after using the product. Therefore, it is necessary to study the essence of technologies that could reduce uncertain images.

In this dissertation, the focus was on how the water contamination problems caused by the flush toilet system could be reduced by changing human perceptions on feces. By using the research method, the convergence of the science and arts methodologies could help to provide the opportunity to consider the essence of scientific technology. In this way, it could be possible to change the relationship between technology and human beings.

CHAPTER 9

Contribution of Convergence Works to the Society

In this chapter, I introduce various results from a research project called *Science Walden*. This project aims to design an alternative community, where scientists and artists work together to solve social problems. My research presented in the current dissertation is based in part on this project. Although various definitions of engineering are used, I would like to define engineering as an attempt for human happiness. Because human happiness is a type of emotion, I believe the identity of engineering is not related only to a science field but is also related to the arts. Another reason for my opinion is that arts can reach directly into the human mind. I formulated the related works with the guidance of Professor Jaeweon Cho, my research advisor, to present the contribution of my research to the field of engineering.

9.1 Feces Standard Money (FSM)

Prof. Jaeweon cho suggested the FSM, based on human feces, as an alternative monetary system. He mentioned that FSM could generate basic income, as long as people deposited their feces into the reactors on a daily basis. He presented this idea in the article *Feces standard money* [84]

> *"Here's an idea which could lead us to a new kind of artistic and scientific world: Can you think of a horizon in which we can both mitigate the problems while keeping the advantages of our current money system? Imagine a scientific method of making odorless powders from our feces, and replacing money with that powder as an alternative to our current system—i.e., "feces standard money (FSM)."*
>
> *Every morning we can put our powder into reactors located in our village to supply food for the microorganisms that can produce various energies such as methane and biodiesel. We can receive a certain amount of FSM in exchange for the powdered feces, and use the FSM to obtain any equivalent value within a system. Feces, like gold, is limited and precious; nobody can make more than a certain limit, and it can be converted to energy.*
>
> *Furthermore, everyone can make feces every day. Whenever we produce and use FSM, it will remind us of our being and existence from the bottom line connection between the FSM and the human being. Thus, FSM has meanings from the perspectives of economy and minds of the human being."*

From his idea, various applications to current human society could be possible. He suggested a FSM-based village community, basic income, and golden electronics. The FSM concept has two major meanings as a viewpoint of contribution to engineering. One is the connectivity between people and

technology and the other is the innovation in human lifestyle. This connectivity is one of the most important factors in the engineering field. The big difference between science and engineering is field applicability. Science mainly focuses on matters or phenomena in nature, but engineering considers the public preference about the developed scientific knowledge. This could be underestimated if the scientific discovery cannot be used in a society. The FSM idea uses feces as a major topic. No one can live without it, and its management technology is most important in human society. Therefore, people can become interested in the technology. Their interest decreases the distance between people and technology. In addition, innovation is one of the goals of the engineering field. People develop many technologies to improve their lives; therefore, the word "innovation" is used often in the science and engineering fields. However, the FSM idea suggests that innovation relates to the humanities. Its perspective of economics and the human being is to realize human happiness, as is mentioned in the preface to this chapter.

9.2 Waterless drying toilet

The waterless toilet has been used in many areas where it is difficult to connect to the water supply or the sewage system. Recently, the composting toilet has emerged as a sustainable treatment system because it reduces water and energy consumption. The evolution of the composting toilet has expanded its application boundary from low-income countries to high-income countries. For example, in Weston, Massachusetts a private K-12 school facility installed composting toilets in the two-story building. In Swannanoa, North Carolina, 10 composting toilets were installed in a college dorm [38]. The drying and combustion types of waterless toilet are commonly used, but, recently, new types of toilets have been designed, such as pyrolysis or solar-heat energy drying facilities. The purpose of developing a waterless toilet is to replace the flush toilet system in an effort to reduce water contamination and to increase the positive perceptions on feces that they could be valuable matters. The original aspect of the waterless toilet is the treatment of the feces, namely, the feces are moved by hand. The manual moving system is related to the experience for increasing positive perceptions on feces. In the waterless toilet, feces change into dried and odorless matters, after which people can use it as a fertilizer or an energy source for methane production by injecting the feces into a bioreactor. In the case of urine, it is collected in a container to make liquid fertilizer, or to recover resources such as nitrogen and phosphorus. Our research team assumed that these experiences with the waterless toilet could increase the positive perceptions on feces. The reason for this assumption is that experiences create perceptions. In our society, with the flush toilet system, it is difficult to receive positive perceptions on feces because people normally think feces are simply

waste. Therefore, the new developed waterless toilet is expected to change our society by changing the perception of people on feces.

- **Operating information about the waterless toilet**: Feces and urine are separated by a special panel, with urine flowing into a container. The feces remain in the heating chamber until they are dried out completely. A rotating blade breaks up the feces lumps, changing them into powder. After drying, the feces are transported to a collector that has a small door. There is a ventilation system in the toilet to remove the malodor that could be generated during drying.

Figure 9.1 Designed waterless toilet system

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